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Transactions of the International Conference on Sanitary Engineering London—1924

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Transactions of the International Conference on Sanitary Engineering London—1924.

PRINCIPAL SUBJECTS DEALT WITH.

State Sanitary Administration.

Works for the Prevention of Malaria and Yellow Fever.

Methods of Disposal of Sewage and Trade Wastes in various Countries.

Treatment of Sludge arising from the Agitation Processes of Sewage Disposal.

Fertilising value of Sewage Sludge.

Sewerage and the Control of Storm Water.

Design of Sedimentation Works.

House Sanitation.

Refuse Collection and Disposal.

National Control of Water Sources.

Water Purification.

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PREFACE

The success of the first International Conference on Sanitary Engineering was undoubted. It was primarily due to the large proportion of the papers read and the speeches made in the discussions being by those who were actually engaged in doing the work they described. This note of intimacy with the subject treated was maintained at all the sessions.

The interest taken in the proceedings by those who attended or contributed papers from many countries and dominions has convinced the Council of the Institution of Sanitary Engineers that there is a widespread desire that another Conference shall be held in due course. The engineering side of sanitation can be more fully and usefully visualised from the international point of view at a Conference called for the purpose than in any other way. The Council feel confident that such Conferences, of which this is the first, are in the public interest, and will become an established feature of international relationships. It remains to determine periodicity and amplitude.

J. S. A.

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CONTENTS

Monday, 7th July.

Chairman—J. S. Alford.

PAGES

OPENING ADDRESS. By J. S. Alford .. .. 1—4

SANITARY ADMINISTRATION IN ENGLAND AND WALES. By I. G. Gibbon. (*Illustrated*) .. .. 5—16

FIFTY YEARS OF SANITATION IN ENGLAND. By H. Percy Boulnois .. .. 17—20

ENGINEERING BUREAU OF THE PENNSYLVANIA DEPARTMENT OF HEALTH. By W. L. Stevenson .. .. .. 21—27

Discussion by J. K. Hoskins, Dr. W. B. Mercer, and T. Chalkley Hatton .. .. 27—29

WORDS OF WELCOME. By the Rt. Hon. John Wheatley .. 30—31

Vote of Thanks to the Minister of Health by J. S. Alford .. 31

RECENT PROGRESS IN MALARIA CONTROL IN THE UNITED STATES. By J. A. Le Prince .. .. 32—36

SOME SANITARY PROBLEMS IN THE MALAY PENINSULA. By Sir Malcolm Watson .. .. 37—41

YELLOW FEVER PREVENTION WORK ALONG THE UNITED STATES-MEXICAN BORDER. By R. E. Tarbett .. .. 42—47

Discussion by Sir Ronald Ross, Dr. Carnwath, Col. W. Clemesha, Sir Malcolm Watson, W. J. E. Binnie, J. K. Hoskins, L. Johnson, Dr. Scharff, A. J. Martin, Dr. Jan Smit, F. C. Temple, and J. S. Alford .. .. 47—52

ELECTRICALLY DRIVEN CENTRIFUGAL PUMPS FOR WATER SUPPLY AND SEWAGE DISPOSAL. By John Bergstrom 53—58

FRICTION OF SEWAGE SLUDGE IN PIPES. By W. Clifford. (*Illustrated*) .. .. 59—65

Discussion by J. S. Alford, Harrison P. Eddy, G. W. Fuller, C. F. Beckenn, G. A. Wigley, J. W. Cameron, A. J. Martin, H. W. Taylor, C. H. Heathcote, L. Johnson and F. C. Temple .. 65—74

Tuesday, 8th July.

Chairman—Arthur J. Martin.

ACTIVATED SLUDGE PLANT, WITHINGTON SEWAGE WORKS. By Dr. Edward Ardern .. .. 75—80

OPERATION OF ACTIVATED SLUDGE PLANTS, HOUSTON, TEXAS. By J. C. McVea .. .. 81—85

Discussion by T. Chalkley Hatton 85

SEWAGE DISPOSAL PLANT FOR THE CITY OF MILWAUKEE, U.S.A. By T. Chalkley Hatton .. .. 86—90

Discussion by T. Chalkley Hatton .. .. 90—92

PAGES

SPIRAL CIRCULATION IN THE ACTIVATED PROCESS. By Charles H. Hurd .. .. 93—97
Discussion by Harrison P. Eddy, H. Kessener, Dr. Calvert, F. W. Harris, G. W. Fuller, F. C. Temple, J. H. Garner, G. Peel Harvey, Harry Taylor, Dr. Jan Smit, Madam Wibaut, F. T. Hambleton, R. Eaton, Dr. Ardern, C. H. Hurd, and T. Chalkley Hatton.. 97—109
COLLOID CHEMISTRY AS APPLIED TO ACTIVATED SLUDGE. By John Arthur Wilson. (*Illustrated*) .. .. 110—115
ELASTICITY OF THE ACTIVATED SLUDGE PROCESS. By Joshua Bolton .. .. 116—121
THE ACTIVATED SLUDGE PROCESS IN INDIA AND THE EAST. By Prof. Gilbert J. Fowler .. .. 122—125
EXPERIENCE IN DEWATERING ACTIVATED SLUDGE. By Langdon Pearse .. .. 126—133
INVESTIGATIONS OF THE FERTILISING VALUE OF ACTIVATED SLUDGE. By Victor H. Kadish .. .. .. 134—138
Discussion by Dr. G. McGowan, W. H. Makepeace, Dr. Imhoff, Dr. Ardern, Harrison P. Eddy, W. D. Scouller, A. J. Martin, Joshua Bolton, Paul Hansen and J. A. Wilson.. .. .. 139—145

Wednesday, 9th July.

Chairman—A. P. I. Cotterell.

INTRODUCTION. By A. P. I. Cotterell 146
SEWER PIPE WORK—ENGLISH PRACTICE. By Edward Willis. (*Illustrated*) .. .. 147—152
Discussion by Prof. E. R. Matthews, W. J. Oakley, T. Chalkley Hatton, W. H. Makepeace and A. P. I. Cotterell .. .. 153—157
SEWERAGE IN LOW COUNTRIES. By B. A. Verhey .. .. 158—164
Discussion by Harrison P. Eddy, A. J. Martin, C. G. Klaarhamer, C. Sharp, F. C. Temple, and A. P. I. Cotterell.. .. .. 165—169
COMBINED SYSTEM OF SEWERAGE WITH LIMITED RAIN-WATER INLET. By Walo von Greyerz .. .. .. 170—175
Discussion by C. G. J. Ratcliff, F. C. Temple, A. J. Martin, Dr. Coleman, H. C. H. Shenton, W. von Greyerz and A. P. I. Cotterell.. .. .. 175—180
UTILISATION OF SEWERS FOR THE DISPOSAL OF SNOW. By Erland Hedstrom .. .. 181—183
Discussion by Harrison P. Eddy, Dr. Coleman and W. von Greyerz 184—185
SANITARY WORK CARRIED OUT IN FRANCE DURING RECENT YEARS. By B. Bezault .. .. 186—188
Discussion by F. C. Temple 189
GRIT CATCHERS, SCREENS AND STORM WATER TANKS IN SEWAGE DISPOSAL WORKS. By F. C. Temple. (*Illustrated*) .. .. 190—195
Discussion by A. J. Martin, W. H. Makepeace, W. Clifford, Dr. Ardern, T. Chalkley Hatton, and F. C. Temple.. .. .. 196—203
HISTORICAL DEVELOPMENT OF SEWAGE PURIFICATION PROCESSES. By J. H. Garner .. .. 204—215
Discussion by W. J. Dibdin .. .. 215—216
DISPOSAL OF INDUSTRIAL WASTES IN THE UNITED STATES. By Harrison P. Eddy .. .. 217—223
PURIFICATION OF TRADE WASTE WATERS IN HOLLAND. By H. Kessener .. .. 224—230
PURIFICATION OF DAIRY TRADE WASTE WATERS. By H. A. van Ysselsteyn. (*Illustrated*) .. .. 231—242
SEWAGE TREATMENT IN SCANDINAVIA AND FINLAND. By Geo. Peel Harvey .. .. 243—252
Discussion by Harrison P. Eddy, Dr. Mercer, Nandy Hoskins, Dr. Ardern, Dr. Calvert, G. W. Fuller, Dr. MacLean Wilson, H. Kessener and G. P. Harvey .. .. 252—260

Thursday, 10th July.

Chairman—H. C. H. Shenton.

PAGES

ENGLISH AND AMERICAN HOUSE DRAINAGE. By George C. Whipple .. .. 261—269
Discussion by Dr. Coleman, W. Scott and H. A. Roechling .. 270—278
OBSERVATIONS ON OPERATING EXPERIENCES WITH CANADIAN SEWAGE DISPOSAL PLANTS. By F. A. Dallyn .. .. 279—287
Discussion by G. W. Fuller 288
REGULATIONS CONCERNING SANITATION OF DWELLINGS. By Prof. Klas Sonden .. .. 289—292
AMERICAN MODEL PLUMBING CODE. By Wm. C. Groeninger 293—297
TWO HOUSE DRAINAGE SYSTEMS—WITH THE ATLANTIC BETWEEN. By John S. Hodgson .. .. 298—301
Discussion by C. G. Klaarhamer, J. W. Lockwood, H. A. Roechling, F. C. Temple, L. Borring, L. Cantor, A. P. I. Cotterell and H. C. H. Shenton .. .. 302—309
MODERN METHODS OF REFUSE COLLECTION. By J. A. Priestley .. .. 310—315
RESUME OF AMERICAN PRACTICE IN THE DISPOSAL OF REFUSE. By Samuel A. Greeley. (*Illustrated*) .. .. 316—324
REFUSE DISPOSAL BY SEPARATION AND SALVAGE. By James Gair .. .. 325—330
Discussion by J. C. Dawes and J. A. Priestley .. .. .. 331—334

Chairman—W. J. E. Binnie.

NATIONAL CONTROL AND ALLOCATION OF WATER SOURCES. By Percy Griffith .. .. 335—340
Discussion by R. G. Hetherington, G. W. Fuller, W. J. E. Binnie, J. Hill, Alderman Johnson, W. von Greyerz, Dr. Jan Smit and C. H. Roberts .. .. 341—347
PRESENT STATUS OF WATER WORKS PRACTICE IN SWEDEN, By Alfred Jerden .. .. 348—352
Discussion by W. J. E. Binnie, Harrison P. Eddy, G. W. Fuller and C. H. Roberts .. .. 353—355
SUPPLY OF DRINKING WATER IN THE DUTCH EAST INDIES. By Dr. Jan Smit .. .. 356—358
OZONIFICATION OF THE WATER OF THE RIVER NEVA. By Prof. S. Rashkovich. (*Illustrated*) .. .. 359—368
PURIFYING THE WATER SUPPLY OF LENINGRAD. By C. Kovroff .. .. 369—374
Discussion by L. Cantor and J. S. Alford.. .. .. .. 375—376

OPENING ADDRESS.

By J. S. Alford, *President of the Institution of Sanitary Engineers.*

This is the first International Conference devoted simply and solely, so far as I am aware, to Sanitary Engineering. The Minister of Health was to have opened it, but unfortunately his duties prevent his being present this morning. He will, however, be here at two o'clock this afternoon, when I hope there will be a large and punctual attendance to hear his address.

On behalf of the Council of the Institution of Sanitary Engineers, I offer you all a hearty welcome, which I particularly extend to the visitors from overseas. England is worth visiting just now, and I hope that those less severe occupations of your stay here will make up for having to attend a conference devoted to technical subjects.

It will not be out of place if I make some observations here on the position of the sanitary engineer in the life of the community, and to comment on some aspects of his calling. In the first place, sanitary engineering is essentially engineering. It is not merely a branch of preventive medicine, although it is closely allied to it. It can stand upon its own feet as a craft which a man, technically capable and mentally efficient, may follow with independence of outlook. I do not myself like the term "sanitary engineer." There is a mingling of the subjective and the objective in it which ought to be got rid of. In other occupations the confusion has been avoided. When we speak of a surveyor of dilapidations, we do not call him a "dilapidated surveyor," and we are always careful to distinguish between a lunacy commissioner and a lunatic commissioner. There ought to be no objection to the term "sanitation engineer," and I suggest for your consideration whether the expression might not be adopted for general use.

The craft of sanitary engineering quite properly extends from the relatively unimportant work of, say, mending hot water pipes to the design and construction of large works for the drainage and water supply of towns and districts. Sanitary engineering, like every other kind of engineering, is based on the public demand for technical skill, which demand is comprehensive enough to include the professional man, the highly skilled artisan and the man of business who is technically qualified.

In this, as in every other branch of engineering, it will never be possible, and it is not desirable, to include within a one and only ring fence any particular section of the craft to the definite and permanent exclusion of the others. The professional man may admit to his societies only by examination, the trades unionist may exclude from his union all who have not been trained by a long apprenticeship, but the public demand has little regard for these things. I have used the word " craft " advisedly because technical advancement is not secured only by the work of men who have passed this or that test, and technical competence over the wide field ranging from handicraft to mathematics is the means by which the craft maintains its position in supplying the community with the thing that it needs.

In a conference like this catholicity must necessarily be an essential feature, and I hope you will agree with me when you look at the programme that this consideration is receiving full attention. To mention only a few items: State Administration, Works for the Prevention of Malaria, the theory of the Centrifugal Pump, certain aspects of Colloid Chemistry, Fertilising values of special forms of sludge, the Emergency Sanitary Works carried out in France, Disposal of Trade Wastes, the interior Plumbing of Houses, special forms of Water Purification—these are sufficient to show that nothing is common or unclean so long as it relates to the craft.

Engineering is a modern occupation and although its followers may have divided themselves into numerous camps in order to take their part more efficiently in the social network, it ought not to be forgotten that the engineers of the early part of the nineteenth century, whose pioneer work was one of the most important factors in making industrial development possible, were men who conducted their business strictly on commercial principles. It was common for such a man to put in a piece of new machinery and to obtain his remuneration by receiving a portion of the saving effected by it. I am not suggesting for a moment, that we should all return to that method, but in these days when examination is piled upon examination and it looks as if the time is approaching when there will be nobody in the country who does not possess a University degree, it is necessary to observe that engineering progress had its roots in the efforts of men who, to say the least of it, did not rank among the most learned in the community. This is not a conference of professional engineers only: it is a craft conference.

We have been fortunate in being able to secure for our meetings the hall of the Royal United Service Institution which is separated only by the thickness of a wall from the Banqueting Hall of Inigo Jones. Every foot of the ground in this neighbourhood is full of historical memories. If you go into the street outside this building and stand opposite the northern corner of the Banqueting Hall you will be on the spot where King Charles I. was beheaded in 1649. On that occasion an opening was broken in the wall of the Banqueting Hall near the second window from the north at a level between the upper and lower

row of windows. The Banqueting Hall had then been in existence for about twenty-five years. It was being planned and its construction might have been commenced when the "Mayflower" sailed from Plymouth. The hall was completed in 1624, and was the only portion erected of an immense royal palace designed by Inigo Jones, which was to have covered twenty-four acres, that is to say, ten times the area covered by Buckingham Palace. The Banqueting Hall remains to-day by common consent the most notable architectural achievement of the period. When Inigo Jones was superintending its erection he was paid 8s. 10d. per day plus £46 per year for a house. Nicholas Stone, the master mason, whose functions must have been intermediate between those of a contractor and a sculptor, was paid 4s. 10d. a day. At that time the old royal palace, which was subsequently destroyed by fire, was in existence and the Banqueting House formed part of the group. At the latter part of the seventeenth century, when Charles II. kept Court at Whitehall, the establishment was conducted on such a prodigal scale that the consumption of meat for a year required 1,500 bullocks and 7,000 sheep. The site of the scene of these hospitalities is now occupied by Government offices, including the Ministry of Health, the Board of Trade and the Ministry of Transport.

There is to be seen in Whitehall to-day a noteworthy juxtaposition which brings before you at a glance the old world and the new. Standing on the spot I have already described, if you look up to the northern corner of the Banqueting Hall you will see a weathercock. That weathercock was put there by James II. in order that from his chamber he might see the direction of the wind and so ascertain whether it was likely that the Dutch fleet would arrive. If without changing your position you turn round, you will see the network of aerials upon the roof of the Admiralty through which the Lords of the Admiralty during the Great War were able to receive directly from the North Sea, news of the Battle of Jutland.

I mention these historical considerations because although visitors from overseas with red books in their hands generally manage to see more of London than a person who lives there, yet the special circumstances of the place of this Conference seem to me to make appropriate a reference to the subject. I may mention to you in confidence that it has been said that if you want to find a man who has never been inside Westminster Abbey, you are more likely to find him in Victoria Street, Westminster, than in any other part of England.

The origin of the suggestion that this International Conference should be held is wrapped in obscurity and none of us are quite certain whether it first arose on this side or in the States, but wherever it came from it was a good suggestion, and having started on the path I see no reason why such conferences should not become periodical. It might even happen that the authorities of Milwaukee or Stockholm might decide to organise an International Exhibition during a year which will be suitable for a Sanitary Engineering Conference.

One word in conclusion upon the differences which exist, and which are likely to increase, between the task of a sanitary engineer in this country on the one hand and in overseas countries on the other. There is a physical limit to which the internal industrial development of this country can proceed and therefore at home here the sanitary engineer is less and less a pioneer, and less and less a hero of spectacular achievement. To put it in the way I have already expressed it to the Institution on another occasion, in England administration has become of more importance than invention. Instances are now comparatively rare in this country in which a great public work can be pointed to as a personal triumph. On the other hand the duties of administrative supervision which are performed by the Ministry of Health are of increasing importance. The work that now has to be done at home is to bring up the backward districts to a predetermined standard rather than to embark on ambitious schemes of raising that standard in specially selected localities. The latter function has not disappeared, but it has become of less importance than it was previously. The result of this is that individual achievement has had to give ground to team work in which the success of every man is more or less conditional upon the success of his colleagues. Instances of notable individual achievement still occur such as that of Sir Ronald Ross, but this, although of profound effect upon engineering practice, was not itself an engineering work.

The PRESIDENT then announced that the first paper to be read was by Mr. I. G. Gibbon (Assistant Secretary, Ministry of Health). It was Mr. Gibbon's province, he said, to preside over that section of the Ministry which had to do with the sanitary engineer, so that there was no one in England more suitable to read the first paper at a conference of this character.

MR. GIBBON, before reading his paper, on behalf of the officers of the Ministry of Health, extended a welcome to the delegates, especially to those from overseas, and said that the officers of the Ministry would be very glad to do anything they could to make the visit of the delegates more helpful to them.

SANITARY ADMINISTRATION IN ENGLAND AND WALES.

By I. G. Gibbon, C.B.E., D.Sc.

1. My subject would easily run into volumes, if treated fully; but I shall be merciful and give you only a brief sketch of the sanitary administration of England and Wales. I shall confine myself to the main outlines and principles; and you must appreciate that exceptions are many, for we are a people who, while not lacking in convictions, as our history richly proves, delight in compromises and expedients.

To understand our general system, you will do well to bear in mind some general truths in addition to the one which I have just mentioned. However much power we may give to an official and however much use we may make of him, back of all is representative democratic control. A saving belief in local government, the fruit of the tradition of years, is firmly implanted in this country.

Central control, while accepted as needful and advantageous, is rarely welcomed; and is stigmatised at the slightest provocation with that mark of the damned called bureaucracy.

As a people, also, we seem never to have become wholly reconciled to the fact that Providence allowed experts to develop; and they are nearly always regarded with some suspicion. There is a redeeming faith and firm reliance on the hard sense of the ordinary man untrammelled with too much knowledge or, as some might gladly put it, too many preconceptions. And, if the truth were told, not a little of our strength as a people comes from this prejudice of independence; and, on the whole, we do manage, sometimes in somewhat blundering ways, to achieve a useful amalgam of specialism and common sense.

AUTHORITIES.

2. The whole of England and Wales—I confine my remarks to England and Wales; Scotland comes under separate administration—is divided into local sanitary areas. These areas are of two classes, rural and urban.

A number of the urban areas are boroughs, but there is no essential difference, as regards duties, between these and the other urban areas, though the boroughs have somewhat higher status and more dignity, chiefly for historical reasons.

The local administration of all these areas is in the hands of elected Councils, except that in the boroughs a fourth of the Council consists of aldermen chosen by the elected councillors. There is only one Council for each Authority; we have no bi-cameral system in local government.

Do not run away with the idea that all these sanitary authorities, or all urban authorities and all rural authorities respectively, are approximately equal in extent or in population. There is, in fact, great diversity; the urban authorities range from big cities like Birmingham with a population of over 900,000 persons (London has a special form of government) and Liverpool with a population of over 800,000 to places where the populations are under 1,000 persons. There are not less than 370 urban authorities with populations below 5,000, and of these nearly 100 have under 2,000. The experienced in administration will appreciate that this large number of small authorities constitutes one difficulty in sanitary administration.

3. The country is also divided into a number of administrative counties. Each county includes a number of Rural Districts and generally of Urban Districts and Boroughs.

The largest towns are administrative counties in themselves, and are called County Boroughs; and they are the one class of authorities which exercise all local government functions within their area.

The County Council does not supervise the other authorities within its area, except to a minor degree. It has to administer chiefly the services which have to be performed as a unit over wide areas, such as education, police and main roads.

The County Councils have, however, a number of sanitary duties such as the treatment of tuberculosis and venereal disease, and, to a large extent, maternity and child welfare. They are also, with the County Borough Councils, the authorities for the treatment of lunatics and the mentally deficient.

It will be seen, therefore, that at present County Councils are not important bodies for the sanitary engineer, but engage especially his professional brother, the man of medicine; and that for the sanitary engineer the local sanitary authorities—the Town Councils (the authorities for the Boroughs), the Urban District Councils and the Rural District Councils—are the bodies of note.

In a number of cases, Local Authorities have co-operated to form joint bodies for common services. There are many joint water boards and a number of joint sewerage boards. In other cases, especially in that of the big towns, the services which are provided by the municipality may also be used by some of their neighbours. Water is frequently supplied in these circumstances, and a large municipality may also treat and dispose of the sewage of a smaller neighbour.

FUNCTIONS.

4. In this country, as in practically all others, public regulation is constantly growing; the sanctity of the Englishman's home, the

"Englishman's castle," has long been invaded, to make sure that the standard of sanitation now demanded by public opinion is observed.

It would take too long to enumerate here all the many sanitary duties which are now under the charge of local and central authorities. In Appendix II., I have set out briefly in diagrammatic form the principal sanitary duties of the several classes of Local Authorities; the first appendix gives information of the number, population, area and rateable value of the different classes.

Expenditure will afford, with some qualifications, the best brief gauge of the amount of work; and I give particulars in Appendix IV. of the expenditure by Local Authorities in England and Wales on sanitary services for the last year for which full particulars are available, that ended on the 31st March, 1922.

The total expenditure on these services during the year reached the great total of over 70,000,000 pounds, or nearly £1 17s. 0d. per head, which gives some indication of the vastness of the services. Moreover, a great deal of sanitary work is in the nature of regulation, for example, of building construction and therefore carries more service than is indicated merely by the cost of the Local Authority.

It is well to state, for the information of those who are not familiar with our practice, that the disposal of sewage in this country is practically in every case a public function for which no special charge is made, except in some cases for trade wastes. Likewise, the collection and disposal of refuse is a public function for which again no special charge is made, except for the disposal of trade refuse.

The supply of water is undertaken chiefly by Local Authorities, but not wholly. The best estimate which I have been able to obtain goes to indicate that approximately 70 per cent. of the population of England and Wales are now supplied with water by Local Authorities; 15 per cent. are supplied by companies (about 12½ per cent. being supplied by statutory companies); leaving about 15 per cent. chiefly in rural districts, which are not provided with a piped supply and depend on local springs and wells and the like.

I should mention that factory sanitation is primarily under a special branch of one of our Central Departments, the Home Office, which has a special staff of factory inspectors; but the Local Authorities have some duties also in this connection.

ORGANISATION.

5. As I have already stated, the work of local sanitary administration is entrusted to local elected Councils. The Councils do not contain any officials. The members do not receive any payment, except that the mayor may receive what is technically regarded as a salary, but is intended to cover his special expenses as mayor—and a lucky man is he if he keeps within it.

A proper notion of the practice of our local government cannot be obtained unless our committee system is understood. The work of the

local Councils is divided among committees—such as Finance Committee, Public Health Committee, Cleansing Committee, Water Committee, and so on. Broadly speaking, it is for each Council to appoint such committees as it thinks fit.

The committees are composed wholly of members of the Council, except that certain classes of Authorities have power to co-opt outside members if they so desire, and, that in a few committees, such as that on allotments, Local Authorities must co-opt outside persons, a compulsion which, on the whole, does not find ready acceptance in the democratic minds of Councillors.

The Committees manage the various service or services which come within their sphere. As a rule, their actions have to be confirmed by the Council. But this confirmation is generally a matter of course, unless the subject be one evoking strong public interest—or, it might be added, the strong preconceptions of some Councillor not on the Committee. Generally, however, Committees cannot incur expenditure except with the previous sanction of the Council, which generally decides only after receiving the views of the Finance Committee ; in financial matters, the control in the best administered Councils is strict.

Some Committees content themselves with the exercise of general control, leaving details to the officials. Other Committees, on the other hand, tend to administer in detail, a system which, I venture to think, is neither in the interests of good administration nor of democratic control, because there is always a danger that the Committee which concerns itself over-much with detail will deprive itself of the means of effective control.

The membership of a Committee is no sinecure ; it involves a great deal of onerous work, and it is a tribute to the public spirit of members that they are ready to devote so much time and trouble to the work.

6. Turning now to the official side, the principal officers who deal with sanitary matters, apart from the Town Clerk or Clerk who deals with all matters of the Council, are—the Medical Officer of Health, the Engineer or Surveyor and the Sanitary Inspector ; in the large places there may also be a separate Water Engineer, a Sewage Works Manager, and a Cleansing Superintendent.

Few rules are laid down either in statutes or in the regulations of Central Departments which state in terms what are to be the duties of the officials (the Medical Officer of Health and the Sanitary Inspector are the ones most regulated in this respect), and Local Authorities have, therefore, a free hand as to the distribution of duties between the several officers.

It is important to note that there is no official in this country corresponding to the City Manager in the United States, or, much less, to the Burgomaster in some continental countries, who is definitely the official head of the local administration. The principal official is the Town Clerk or Clerk of the Authority ; but the measure of his power and influence depends primarily upon his personal qualities. All the

officials are under the close supervision of the committee or committees dealing with their work; and, as already mentioned, the degree of responsibility given to the official differs in different places. In very few cases is an official legally able to take action on his own responsibility, especially if the individual liberty of the citizen is affected; the general rule is that any proposal of the official has to be confirmed by the Council, and it then becomes their action. The British people like their officials—but do not allow them to bite too deeply lest they run mad.

CENTRAL DEPARTMENT.

7. One of the respects in which local administration here is most distinguished from that in other countries is in relation between the Local Authorities and the Central Department, though it is interesting to note that elsewhere, notably in the United States, there is a definite tendency to approach to our practice.

In this country, the connection between the Ministry of Health and the Local Authorities is a very close one. The functions of the Ministry of Health, which is really also a ministry of local government, may broadly be stated to be, in this respect, the general supervision of the work of Local Authorities in certain matters, the confirmation of certain classes of important proposals by Local Authorities and (on the whole a late development) the distribution of national grants for local services.

I wish to correct any impression that some of you may have that the Local Authorities are held in leading strings, that the Ministry of Health is the nurse and Local Authorities the babies. It is a general principle of our constitution that Local Authorities can exercise only those powers which have been expressly conferred upon them, either by general statutes or statutes (called Local Acts) applying only to particular localities; but Central Departments are similarly restricted, and the Courts will show them no mercy if they go beyond the bounds of their authority.

Local Authorities have, in fact, a wide range of power and much liberty of action. The supervision of the Central Department is in many matters a general one and, on the whole, the more general the better, though, where grants are distributed, the fears and caution of the purse almost inevitably lead to detail.

Among functions of the Central Department, I may mention in particular:—

(1) The sanctioning of loans. In general, Local Authorities cannot incur capital expenditure without the consent of the Minister of Health or of Parliament. It follows, therefore, that capital expenditure on most big schemes of sewerage and sewage disposal, many of the water undertakings, refuse disposal, and the like, come before the Ministry, and are investigated by them before sanction is given to the raising of loans for them. When the

application is made direct to Parliament in a Local Bill, the Ministry report to Parliament on the proposals.

(2) By-laws proposed by the Local Authority for the regulation of new buildings, slaughter-houses, markets, and the like, have to be confirmed by the Ministry before they come into force. To help Local Authorities, the Ministry have prepared codes of model by-laws on various subjects; I give in Appendix III. a list of the subjects of sanitary interest on which by-laws may be made, and, as likely to be of special value to some members of the conference, indicate those subjects for which model codes have been prepared by the Ministry.

(3) The Ministry of Health is the appellate body in certain classes of cases: for example, as to whether a house is so unfit that it should be closed, and as to whether work done by a Local Authority because the sanitary accommodation was inadequate, is reasonable. In a number of other cases, the appeal lies, not to the Central Department, but to the local magistrates.

(4) National grants in aid of certain specific services have been given in recent years, in particular towards maternity and child welfare and the treatment of tuberculosis and venereal disease, and, especially during the last few years, for housing—with which we are still struggling, like most other countries, only, I think, a little more intensely.

(5) As already indicated, the Ministry investigate all proposals of water supply; in addition, they are making a general water survey and, in conjunction with an Advisory Committee, are taking steps towards the formulation of a national water policy.

(6) I may mention also that the Ministry of Health is the central authority for town planning, which is of close concern to the sanitary engineer.

8. With regard to the organisation of the Central Department, a fundamental matter of first importance in the general government of the country is that all the acts of the Department are those of the Minister, who is responsible to Parliament, and may be questioned at any time, and, indeed, frequently is questioned, and brought to book on any action which has been taken by his Department—and although one may be inclined at times in one's haste to make some harsh remarks about the occasional triviality of Parliamentary questions, there is no doubt that they provide a most salutary brake on that bugbear of British democracy, the bureaucrat; they always provide means of putting salt on the official tail.

The Minister himself manifestly has time to deal, in addition to his Parliamentary work, only with matters of important policy or with specially important cases. In the Department there is a staff of administrative and technical officers who hold permanent appointments with security of tenure. The responsibility for deciding cases rests on the administrative officials; but they act after receiving the recommenda-

tions, where necessary, of the appropriate technical advisers, whether medical, engineering or architectural.

As regards the engineering staff, which is the one of most interest to this Conference, it consists of a Chief Engineering Inspector, a Deputy Chief, fourteen Engineering Inspectors, a Chemical Inspector, and a Public Cleansing and Salvage Inspector. The ample measure of work which passes through their hands may be gathered from the fact that during the year 1922—23 works representing loans to a total of no less than £16,000,000 passed under their investigation and, of course, they have a great deal of work quite apart from applications for loans for public works.

In a large proportion of the cases which come before them, the proposals are investigated locally. In the more important cases, a public inquiry is held in the locality in addition to the personal inspection, and ample opportunity is given to persons concerned to have their say for or against the proposals, and, though this may sometimes be done at wearisome length, the publicity provides a valuable safeguard. At some of these local inquiries, the Inspector may find himself confronted with a formidable array of barristers of the highest standing.

It will be appreciated that the Inspector must be much more than just an engineer; technical qualifications he must have, and those of the best, but if he is to be the paragon of excellence which is required, and to render the best service to the country, he must have a rich portion of administrative sense, be more than a bit of a lawyer, and very much of a diplomat.

Members of the engineering staff are recruited from competent men of wide experience, not by examination, as is usual in the case of the administrative staff, but by selection. A man is not likely to be of much service unless he has already developed, before he joins the Service, the fundamental technical qualifications which are required; but his subsequent value will rest very largely upon the experience, which is of very wide range, which he acquires in his investigations up and down the country. He becomes a very compendium of information and experience, especially if, as is generally advisable, he specialises in certain classes of work, and acquires a fund of knowledge which he places freely at the disposal of the various Authorities with which he has to deal.

As you will gather, it is important for efficiency that there should be close informal relations between the officials of the Central Department and of Local Authorities, and I can assure you that it has always been one of the objects of the Ministry of Health to encourage these informal relationships in the most generous measure.

CONCLUSION.

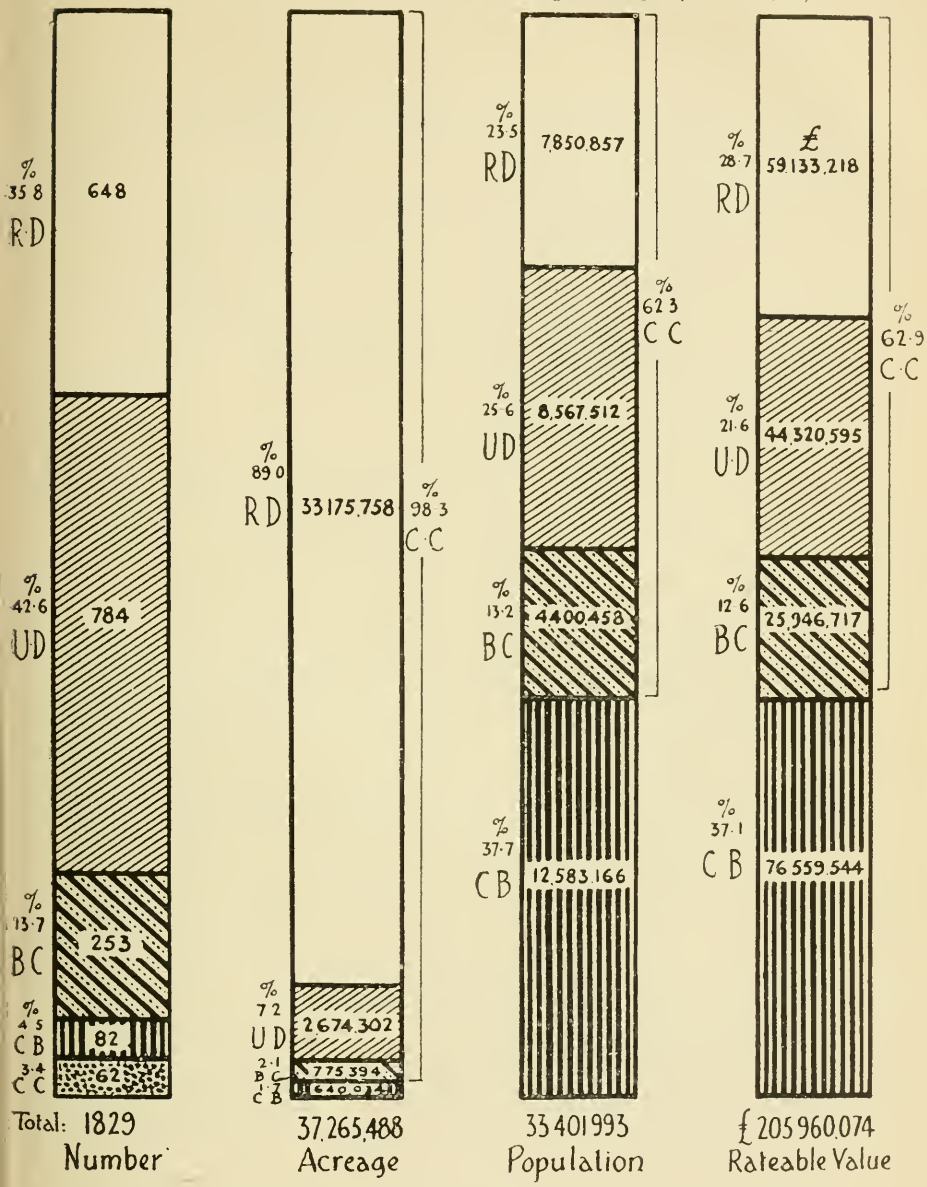
9. I have given you a brief outline of the sanitary administration of our country. The basis is broadly democratic, and, while full use is made of expert officials, they are always subject to control. Local

autonomy is tempered by a restricted measure of Central control, and the combination has, on the whole, proved to be for the public benefit.

The effectiveness of our system depends less on statutory provisions than on good intent and mutual helpfulness. Back of all the machinery of government lies the public spirit of men and women ready to give unsparingly of their labour to the general good, and the live interest of the ordinary citizen in his town and country and his sense of good government. That, although much, very much, still remains to be done, we have not been lacking in these qualities, and that our general system has been effective, is abundantly proved by the enormous strides which have been made during the last hundred years in the health, comfort and amenity of life—and in no less measure by the prevailing dissatisfaction even with the results already achieved and the fixed determination, despite the difficulties of rates and taxes and many another of our post-war troubles, and irrespective of party, to secure still further improvements which will add to the efficiency of our people, and will lead into channels of peaceful achievement those inspirations for a fuller life which are at the same time one of the dangers and one of the credits of modern democracy.

APPENDIX I.

Diagram shewing the numbers, acreages, populations, and rateable values of the districts of the principal classes of Local Authorities in England and Wales (outside London) together with their percentages (Census 1921).



REFERENCE.

CC=County Councils; CB=County Borough Councils; BC=Non-County Borough Councils; UD=Urban District Councils; RD=Rural District Councils.

NOTE:—The Administrative County of London has an acreage of 74,850; a population of 4,483,249; and a rateable value of £48,898,546. The Local Authorities in the county are the County Council, the Common Council of the City of London, and the 28 Metropolitan Borough Councils.

APPENDIX II.

PRINCIPAL SANITARY POWERS AND DUTIES OF LOCAL AUTHORITIES (OUTSIDE LONDON).

Rural District Councils

Water supply.
Securing that every dwelling-house has water-supply available within a reasonable distance.

Urban District Councils

Housing.
Provision of houses for working classes. Small schemes for reconstruction of unhealthy areas. Closing or demolition of unfit houses. Requiring owners to put working-class houses into habitable condition. Prevention of overcrowding. Removal of obstructive buildings. Registration, inspection and regulation of common lodging-houses. Securing the proper sanitary condition of all premises.
Sewerage and sewage disposal.
Public cleansing.
Removal of house refuse.
Cleansing of earth closets, privies, ash-pits and cesspools.
Detection and abatement of nuisances (including smoke abatement).
Infectious diseases.
Notification and prevention of infectious diseases.
Provision of hospitals.
Provision of nurses for cases of infectious disease outside hospitals.
Food.
Enforcement of statutory provisions prohibiting sale of tuberculous milk. Inspection of foods for human consumption. Registration, etc., of dairies, cowsheds and milkshops. Control of retail bakehouses.
Maternity and child welfare.
Provision of open spaces.
Provision of cemeteries, crematoria and mortuaries.
Prevention of pollution of rivers.
Inspection and regulation of canal boats.
Cleansing, etc., of verminous persons.
By-laws as to buildings, common lodging-houses, and houses let in lodgings, cemeteries, etc., cleansing of privies, ash-pits, cesspools, and footways, removal of house refuse, tents, vans and sheds used for human habitation and hop, fruit and vegetable pickers.
(Certain of the urban powers can be conferred on Rural District Councils by an Order of the Minister of Health.)

Non-County Borough Councils

Improvement of unhealthy areas.
Provision, etc., of:—
Public walks and pleasure grounds. Baths and wash-houses. Markets and slaughter-houses. Public sanitary conveniences. Ambulance service.
Cleansing and watering of streets.
Execution of Burials Acts (where District Council are a Burial Board).
Supervision of offensive trades.
By-laws as to new streets and buildings (additional powers), pleasure grounds, baths and wash-houses and public bathing, markets, slaughter-houses, public sanitary conveniences, offensive trades, keeping of animals, and nuisances from rubbish, snow, etc.

County Borough Councils

Enforcement of Food and Drugs Acts and of law as to licences for sale of milk (if Quarter Sessions Borough or having separate police force).
Various powers and duties as to diseases of animals (except in boroughs of less than 10,000 population).

County Councils

Provision and maintenance of mental hospitals.
Establishment of hospital districts for infectious diseases.
Provision of institutions for tuberculosis.
Treatment of venereal diseases.
Maternity and child welfare.
Enforcement of Sale of Food and Drugs Acts and of statutory provisions relating to the sale of milk (except in Quarter Sessions Boroughs over 10,000 population and boroughs having a separate police force).
Prevention of river pollution.
Various powers and duties as to diseases of animals (except in boroughs of 10,000 population or over).
Report of County Medical Officer of Health on general conditions throughout county.

If Local Sanitary Authority in default:—
Provision of sewerage and water-supply and carrying out of any provisions of Public Health Acts in rural districts, if complaint made by Parish Council.
Housing.
Provision of houses or improvement schemes, if empowered by Minister of Health.
Closing or demolition of unfit houses in rural districts
Registration, etc., of dairies, cowsheds and milkshops, if empowered by Minister of Health.

APPENDIX III.

BY-LAWS.

Local Authorities have powers to make by-laws, subject to confirmation or approval by the Minister of Health as to the following (among other) subjects; and the Ministry have codes of model by-laws for nearly all these subjects :—

New streets and buildings.

(There are three model codes, one for Boroughs and large Urban Districts, one for Rural Districts, and an intermediate code for residential Urban Districts and Rural Districts of an urban character).

Alteration of buildings.

Drainage of existing buildings.

Houses let in lodgings or occupied by members of more than one family (By-laws under Public Health Act, 1875).

Houses intended or used for occupation by the working classes and let in lodgings or occupied by members of more than one family (By-laws under Housing Act, 919).

Common lodging houses.

Tents, vans, sheds and similar structures used for human habitation.

For securing the decent lodging and accommodation of persons engaged in hop picking or in the picking of fruit and vegetables.

Underground rooms as sleeping places.

The prevention of nuisances arising from snow, filth, dust, ashes and rubbish, and the prevention of the keeping of animals on any premises so as to be injurious to health.

Nuisances in connection with the removal of offensive or noxious matters.

The cleansing of footways and pavements ; the removal of house refuse from premises ; and the cleansing of earth closets, privies, ashpits and cesspools belonging to premises.

For imposing on the occupier of any premises duties in connection with the removal of house refuse, so as to facilitate the work of collection.

Slaughterhouses.

Markets.

Offensive trades.

Removal to hospital of persons brought within the district of a Port Sanitary Authority by any ship or boat, who are infected with a dangerous infectious disorder.

For preventing the waste, undue consumption, misuse or contamination of water.

Cemeteries.

Mortuaries.

Public baths ; public wash-houses ; open bathing place ; duties of the officers and servants of the public baths and wash-houses ; duties of the superintendent of the open bathing place.

Public bathing.

Pleasure grounds ; recreation grounds ; open spaces.

Village greens ; commons.

Pleasure boats and vessels.

Provision of means of escape in case of fire in certain factories and workshops.

Conduct of persons using or frequenting public sanitary conveniences.

Cleansing of cisterns (London only).

APPENDIX IV.

EXPENDITURE OF LOCAL AUTHORITIES IN ENGLAND AND WALES ON SANITARY SERVICES IN THE YEAR ENDED 31ST MARCH, 1922.

Purpose or service.	Total expenditure (to the nearest £1,000).			Expenditure per head of population (to the nearest 1d.).			Net expenditure (to the nearest £1,000) after allowing for receipts for services).
	Otherwise than out of loan.	Out of loan.	Total.	Otherwise than out of loan.	Out of loan.	Total.	
1.	2.	3.	4.	5.	6.	7.	8.
	£	£	£	£ s. d.	£ s. d.	£ s. d.	£
1. Waterworks	16,438,000	5,515,000	21,953,000	8 8	2 11	11 7	3,824,000
2. Sewers and sewage disposal	8,948,000	3,531,000	12,479,000	4 9	1 10	6 7	8,194,000
Cleansing:—							
3. House refuse, collection, disposal and destruction of	7,874,000	270,000	8,144,000	4 2	2	4 4	7,417,000
4. Scavenging and watering of streets	4,454,000	—	4,454,000	2 4	—	2 4	—
Hospitals, sanatoria, dispensaries, etc.:							
5. Diseases (fever, diphtheria, smallpox, etc.), other than tuberculosis and venereal diseases	4,321,000	103,000	4,424,000	2 3	1	2 4	4,113,000
6. For tuberculosis	3,338,000	519,000	3,857,000	1 9	3	2 0	2,865,000
7. For venereal diseases	460,000	—	460,000	3	—	3	452,000
8. Parks, pleasure grounds and open spaces	3,921,000	877,000	4,798,000	2 1	5	2 6	3,023,000
9. Maternity and child welfare	2,004,000	107,000	2,111,000	1 0	1	1 1	1,531,000
10. Baths, wash-houses and open bathing places	1,804,000	123,000	1,927,000	11	1	1 0	1,029,000
11. Cemeteries	1,463,000	174,000	1,637,000	9	1	10	561,000
12. Vaccination	173,000	—	173,000	1	—	1	173,000
13. Port sanitary service	105,000	—	105,000	1	—	1	87,000
14. Salaries of medical officers of health, inspectors of nuisances and health visitors (so far as not allocated to specific services)	1,345,000	—	1,345,000	9	—	9	1,335,000
15. Other health services	1,856,000	379,000	2,235,000	1 0	2	1 2	1,378,000
16. Total for all sanitary purposes and services	58,504,000	11,598,000	70,102,000	1 10 10	6 1	1 16 11	35,982,000
17. Housing	10,214,000	81,726,000	91,940,000	2 3 2	5 4	2 8 6	9,107,000
18. Land drainage and embankment, and river conservancy	865,000	245,000	1,110,000	5	2	7	626,000
19. Total for all purposes and services (sanitary and other) of local authorities	365,026,000	128,730,000	493,756,000	9 12 9	3 7 11	13 0 8	243,566,000

* For this service the only figures available are those of expenditure out of revenue.

NOTE.—The above table should be read subject to the following qualifications:—

(1) Because of the high rates of wages and prices then ruling, the expenditure for the year ended March, 1922, is much above normal.

(2) The capital expenditure, out of loans, on housing (item 17; it is not shown separately as a sanitary service though in some respects it may be so regarded) was exceedingly heavy during this year because of the special scheme which was then in force, and accounted for over 60 per cent. of the total loan expenditure for the year.

(3) It has to be remembered that, while expenditure is a good indication of the work of Local Authorities where services are rendered, it is not a good indication where the Local Authority simply exercises control, such as in the administration of by-laws.

FIFTY YEARS OF SANITATION IN ENGLAND.

By H. Percy Boulnois,

Fellow, Past President and Gold Medallist of the Institution. Late City Engineer of Liverpool, and late Deputy Chief Engineer Local Government Board.

It is just over fifty years ago that I entered municipal life as a city surveyor. Many changes have occurred since then and much advance has been made in our knowledge of sanitation or, what is defined in the Imperial dictionary, as "the adoption of sanitary measures conducing to preserve the health of a community." The great English "Public Health Act of 1875" had not come into being, so that the powers to enforce sanitary measures were very meagre before that date. Even after the passing of this Act, considerable difficulty was often experienced in persuading people that health was as important as money and it is difficult to realise, at the present date, the obstruction and apathy that were encountered by the officials in trying to carry out sanitary improvements.

Let me try and recall some of the conditions that existed, and which came under my own observation during the period I am attempting to describe.

A large number of main sewers had flat inverts, if they had any inverts at all, for many of them were constructed in the rock without lining of any description and were merely elongated cesspools. The house drains were mostly brick barrels, or inferior earthenware pipes, connected directly to the sewer without any intercepting trap; such traps as existed were ordinary siphons without any air-inlet and were worse than useless, as they acted as catchpits and were frequent causes of drain stoppages. In consequence of this and the bad construction of the sewers the manholes in the streets gave off the most offensive odours, due to the decomposing sewage, and many pamphlets and papers were written on the subject of the ventilation of sewers and all sorts of schemes were introduced to cure the evil. We hear very little nowadays of complaints of smells from manholes as the more scientific construction of sewers and house drains has cured the causes of these former emanations. Be it remembered also that fifty years ago sewers

were not constructed in straight lines between the manholes, as they are now, but followed the curves of the streets. This innovation and the more scientific design of sewers and drains on hydraulic principles has made a vast change in what was at one time a huge controversy as to the danger of open manholes in the streets.

Then came the important question of how to deal with the sewage at the outfall. It is almost impossible now to realise the various views that were held by sanitary engineers of high standing on the subject. There were practically two schools of thought, one that held that all sewage should go back to the land and the other that decomposition should be arrested by chemical treatment. The former method has of course held its own, where suitable conditions and land were obtainable, but with regard to the latter an immense number of palliatives were suggested, and tried, at huge expense with very little, if any, success. Hundreds of patents were taken out and experiments made, but it was always found that what was called secondary decomposition set in sooner or later in the effluent which shewed that chemical treatment could only "scotch" and not kill decomposition. It is curious to reflect how misguided we all were not to realise that all nature's laws are here for our benefit if properly guided and not thwarted.

It was not till about the year 1894 that this was recognised by a Mr. Donald Cameron, the then City Surveyor of Exeter, who introduced what he called the septic tank which revolutionised our ideas on sewage treatment, and on which discovery all the subsequent improvements have been founded, even including the activated sludge process which, so far, seems to be the last word on sewage treatment.

Much might be said on the improvements that have taken place with regard to public water supplies, both in purification and distribution, did time permit ; suffice it to say that the domestic filter, that one saw then in almost every house, has now disappeared. What better proof could one have of the sanitary improvements which have taken place in this direction alone in the last fifty years ?

Turning to house sanitation the advances in this direction have been prodigious. Even less than fifty years ago the cumbersome insanitary "pan closet" held its own with the "long hopper." Soil pipes existed inside the houses and the plumber had to be educated in sanitary work. Bathrooms were infrequent, even in good houses, and sinks and lavatories were "trapped" in a very perfunctory manner. "Bell traps" were prevalent in basements and elsewhere which speedily lost the necessary water seal and became open doors for the free admission of the air from the sewer. It would be impossible, in the space at my disposal, to refer to the numerous insanitary conditions which prevailed in houses at that period; anyone wishing to test the accuracy of my statements or to further study the lamentable lack of sanitation, as we know it to-day, has only to read that remarkable book "Dangers to Health," by the late Dr. Pridgin Teale to be able in some measure to visualise those conditions. This book, with its strikingly coloured illustrations, did much to educate the public in matters of sanitation.

With regard to the temporary storage, collection, and final disposal of house refuse ; there were literally acres of open brick dustbins in every large town and city. The modern galvanised "sanitary dust pail" was unknown. These brick dustbins were mostly uncovered and often remained unemptied for weeks, if not months ; even the model by-laws, issued under the powers of the Public Health Act, 1875, contained a number of clauses regulating their construction. The collection of the refuse, often in the hands of a contractor, was executed in a very perfunctory and intermittent manner and its ultimate disposal was equally unsatisfactory and insanitary. In the year 1882 I gathered some statistics on the methods of disposal then in force, with the following result. In many towns it was stated that the whole of the refuse was used by brickmakers, in others it was simply tipped to waste. In one case the answer was "Sold by auction twice a year" but to whom it was sold and for what purpose did not transpire. In a few towns it was "mixed with lime and used as manure on the fields." From one town the answer was "given or thrown away" which seems an easy method of disposing of the subject if not of the refuse. The most favoured method, where it could not be barged away to sea, was that of carting it away to some spot outside the town and there filling up pits and old quarries. In many cases these dumps afterwards came into the market as building sites with unfortunate results to the inhabitants. It was not till the introduction of the so called "refuse destructors" that any change in these insanitary methods took place.

Closely allied to this question of dealing with ordinary house refuse, was that of dealing with the fæcal matter and urine from houses in towns imperfectly sewered. It is almost incredible that fifty years ago and even later there were advocates of what was called the "interception or dry process," which consisted in placing tubs, or pails, in the houses as substitutes for water closets. These receptacles were periodically collected and taken in vans to a depôt where the contents were dried and converted into manure. This disgusting process was in vogue in some of our manufacturing towns for some years but has now happily disappeared.

The conditions under which the people lived in the courts and alleys of many of our most prosperous cities and towns would take too long to describe. In the course of my professional duties I have had to inspect a considerable number of these human rookeries. It would require the pen of a Zola to describe the insanitary conditions of the crowded houses and of the courts or alleys themselves. These slum areas, a legacy from our unscrupulous and greedy ancestors, have cost many millions of money to demolish, and there is still much work in this direction to be done. Model labouring class dwellings were but few fifty years ago, and the scheme for the provision of premiated houses at unremunerative rents had not been considered as coming within the range of "practical politics."

The position, construction, and management of slaughter-houses, stables, fell-mongers, and other "offensive trades" premises have been

greatly improved. The purification of nearly all trade wastes has been accomplished. Parks and open spaces have been provided, wider streets secured, public conveniencies constructed, and numerous other measures adopted "conducing to preserve the health of a community." Even the surfacing of our streets and roads with impervious materials has been a sanitary measure, for obvious reasons.

This short paper has endeavoured to recall some of the sanitary improvements that have been evolved during the last fifty years in this country. There is, however, no finality in science, and probably a writer in the year 1974 will have much to say as to our want of knowledge in 1924 and of our mistakes.

In the words of a forgotten poet, it behoves young engineers of the present day to

Take the spade of perseverance,
  Dig the field of progress wide,
Every rotten root of error
  Harrow up and cast aside.

ENGINEERING BUREAU
of the
PENNSYLVANIA DEPARTMENT OF HEALTH.

By W. L. Stevenson,

Mem.Am.Soc.C.E., Chief Engineer, Department of Health.

The Department of Health of the Commonwealth of Pennsylvania was created in 1905 by an Act of Legislature and one of the first divisions erected therein was the Bureau of Engineering. During the past eighteen years the available funds, personnel and scope of the Bureau have markedly increased so that now the major activities include the following :—

WATER.

The examination of plans of new public waterworks projects or extensions or changes in existing waterworks, (1) field and laboratory investigations thereof and recommending their approval, modification or rejection ; (2) supervision over the operation of public waterworks, so far as quality of the water is concerned ; (3) examination and certification to the United States Government (4) as to quality of water used to fill passenger drinking water-tanks on railroad trains and boats engaged in inter-state traffic.

SEWERAGE.

Examination of plans of all public and private sewerage projects, including treatment of sewage ; (5) field investigations and recommending the approval, modification or rejection of the plans ; (2) and supervision of the operation of sewage treatment works so far as proper operation and quality of effluent is concerned (6).

MILK.

Administration of rules and regulations requiring medical examination of milk handlers (7) and the pasteurization (8) of all milk sold for human consumption, except that milk obtained from tuberculin tested herds may be sold as raw milk. Assisting local health authorities in the preparation and enforcement of local milk regulations.

NUISANCES.

In the rural part of the State where there are no local boards of health (9) inspection, service of abatement notices and assisting in prosecution of violation of law relative to public health nuisances (10).

Referring to local health authorities (11) complaints relative to public health nuisances in incorporated municipalities (12) and assisting and co-operating when requested or needful to secure abatement.

HOUSING.

Administration of law relative to sanitation in boarding, lodging and tenement houses which require adequate and pure water-supply, proper sanitary means of excreta disposal, ample light and ventilation in sleeping- and living-rooms, general cleanliness of premises and provisions to prevent overcrowding.

FAIRS.

Inspection and supervision of water supply and disposal of excreta, manure and garbage at about 80 county fairs which are held in the autumn of each year (13).

CAMPS.

Examining and advising on water-supply, excreta disposal and general sanitation in summer camps for boys and girls.

SANITATION.

Advising municipal officials on problems of general sanitation, such as water-supply, installation of public sewers and sewage treatment works, garbage and refuse collection and disposal, etc., but always in a general way and with the recommendation that private engineering services be employed by the municipality to make detailed study and specific recommendations (14).

TYPHOID.

Co-operating with medical officers of the Department of Health to determine the cause of epidemics of typhoid fever and other water or milk borne diseases and to adopt engineering measures to eliminate the cause and prevent recurrence (15).

STREAM POLLUTIONS.

From 1905 to 1923, the department's jurisdiction over stream pollutions was limited to the discharge of sewage and other substances prejudicial to the public health and to the abatement of public health nuisances. The legislature of 1923 included in a general law for the reorganisation of the State Government, provisions creating in the Department of Health a "Sanitary Water Board"(16), in which is vested the administration of all State laws relative to stream pollution, and designating the Department of Health as the enforcing agent of the Board.

The laws administered by the Board include, *inter alia*, authority to prohibit or to determine the conditions under which sewage may be

discharged to the waters of the State(17), the prohibition of the discharge of any substance deleterious, destructive or poisonous to fish(18) unless every reasonable and practicable means have been used to abate or prevent pollution. The Board is also authorised to study, investigate and report upon ways and means of eliminating and preventing stream pollutions which are detrimental to the public health, the health of animals, fish and aquatic life or to the recreational use thereof.

The policies of the Board include *inter alia*—

That streams which have been approved as sources of public water-supply after filtration should, in addition to being reasonably clean, provide a raw water sufficiently low in organic and pathogenic bacterial content that it can be safely and reasonably economically purified for domestic purposes.

That streams which have been approved as sources of public water-supply with only chlorination of the water before use should be kept free from all artificial sewage pollution unless there is adequate assured long-time storage, and in such cases any sewage effluent admitted to such streams should be adequately disinfected as a further safeguard.

Requirements made to restore sewage polluted streams, or to maintain clean streams in a clean condition should be begun at the head waters and progress down-stream. Requirements made to protect sources of public water supplies in general and subject to local conditions should be begun at the first source of sewage contamination above the water-works intake and progress up stream.

The most important resolution (19) of the Sanitary Water Board is one providing for classifying the streams into three major groups, to wit :—

Class A : Unpolluted or uncontaminated from any artificial source and any sewage or industrial waste hereafter produced on the watershed shall be treated to the highest degree so as to maintain them in a clean and relatively pure condition.

Class B : More or less polluted and where degree of treatment of polluting matter will be determined by local conditions.

Class C : So polluted by industrial waste that it now appears against the public interests to attempt to restore them to a clean condition.

The Bureau of Engineering is the active agent of the Sanitary Water Board, making the investigations, submitting reports, preparing permits and recommending policies ; in addition to which the activities enumerated in the forepart hereof are carried on.

ORGANISATION OF BUREAU.

The Bureau has a total personnel of thirty-seven of which thirteen are licensed professional civil engineers.

The employees may be considered in four groups as follows :

Executive—A Chief Engineer and an Assistant Chief Engineer.

The Staff—Five Engineers, each a specialist respectively in Water-works and Sewerage, Milk Control, Laboratory, Housing and Civil Engineering.

The Field Force—Seven District Engineers and seven Assistant Engineers engaged in original field and office work.

A Clerical, Stenographic and Drafting Force.

The headquarters of the Bureau are in Harrisburg, the Capitol of the State, centrally located as to transportation, which is by means of eight State owned and maintained automobiles.

The Milk Control Work is in charge of the Milk Control Engineer. The Chemical Laboratory for analyses of water, sewage, trade wastes and research, is in charge of the Chemical Engineer. Nuisance Abatement and Housing Work is under the direction of the Housing Engineer. Examination of plans of structures, map making and kindred work is in charge of the Civil Engineer.

Each District Engineer is in charge of a definite part of the State, and has charge of the original field investigations and examinations of plans, report writing and kindred work in his district, under policies established or approved by the Chief Engineer.

The allotment of funds to the Bureau for the years 1923 and 1924 was $267,000, which includes salaries and expenses.

Nineteen years ago there was no organised, practical State control over the sanitary quality of public water-supplies, the sewage pollution of streams, the disposal of human excreta, and other primary causes of the typhoid epidemics then so common throughout the State.

The administration of laws controlling these and like matters by the Bureau of Engineering is believed to have been the major factor in the 99 per cent. reduction in the typhoid fever rate and the estimated saving of 50,000 human lives. Does not this show the value of the Engineer in public health work? It does surely demonstrate that it is essential for the Engineer and the Doctor to be closely allied and to stand shoulder to shoulder in the great altruistic service of protecting and promoting the public health for the betterment of mankind.

NOTES.

THE FOLLOWING DATA ARE GIVEN TO AMPLIFY THE GENERAL STATEMENTS IN THE PAPER.

(1) Examination includes determination as to conformity with good engineering practice, adaptability of proposed processes of purification to produce a wholesome, palatable drinking water and sufficiency of the proposed source to meet present and reasonable future demands.

(2) The permit, required by law, is prepared by the Bureau and signed by the Secretary of Health.

(3) There are 650 public water-supplies in the State serving over 6,000,000 population. Superintendents required to submit to Bureau, usually weekly, reports of operation and data showing quality of water.

Engineers inspect works at frequent intervals to observe operation and if needful recommend improved methods of operation or require safeguards.

(4) In accordance with Federal law.

(5) Examination includes determination as to conformity with good engineering practice, adequate capacity for future flow in sewers and ample gradient to produce self-cleansing velocity with present flow, sufficiency of pumping stations, adaptability of processes of treatment to the particular sewage and sufficiency of processes to produce an effluent of quality needed to protect the receiving body of water, and that works are so designed as to be capable of additions for increased rates of flow and higher degree of treatment if and when required.

(6) There are 200 sewage treatment works in the State. Operators of reasonable size works required to submit to Bureau, usually monthly, reports of operation of sewage treatment works, giving essential data on operation and showing quality of effluent. Engineers inspect works to observe operation and if needful recommend improved methods of operation or require changes to improve conditions.

(7) To show freedom from communicable diseases transmissible through milk.

(8) For thirty minutes at 145°F. using a recording thermometer.

(9) In second class townships having a density of population less than 300 per square mile. Aggregate population over 2,000,000.

(10) Public health nuisances as defined in regulations include—Privies or cesspools where flies may have access to excrement or which discharge over the ground or to the waters of the State, nightsoil disposed of within town limits or within 700 feet of habitation or deposited in waters of the State ; maintenance of privy or cesspool on premises to which a lawful sewer is accessible ; kitchen or laundry water, garbage, offal, pomace, dead animals, decaying matter or organic waste matter deposited on ground or in the waters of the State ; manure prejudicially affecting water-supply or breeding flies ; stagnant water breeding mosquitoes ; noxious odours or substances detrimental to health ; unclean or insanitary slaughter houses, etc. ; piggeries prejudicially affecting water-supply or breeding flies ; source of water-supply on private premises to which the public has or may have access which is polluted or so situated or constructed that it may become polluted and injurious to the public health.

(11) State law makes it the duty of local Boards of Health to administer all State health laws and regulations of the State Department of Health.

(12) Aggregate population over 6,000,000.

(13) Each fair lasts three days, people from the surrounding countryside attend in dense crowds aggregating over 2,000,000.

(14) On farms there are few engineering problems within the jurisdiction of the Bureau and the largest cities generally engage competent engineers to solve their problems, so that the duty of the State in these

large cities is largely review and criticism of design to see that it is in accordance with the State's broad policy.

The smaller municipalities, however, require considerable help and guidance. The scope of the work is shown by the following data from the 1920 census :

			1920 population.
668	incorporated municipalities having less than 2500 population of which 426 have less than 1000 population		= 2,170,842
144	towns with population	2,500 to 5,000	
93	,, ,, ,,	5,000 to 10,000	
57	,, ,, ,,	10,000 to 25,000	
16	,, ,, ,,	25,000 to 100,000	= 2,950,126
4	cities over 100,000		2,657,689
	on farms		941,360
	Total population		8,720,017

(15) When the Department was created in 1905 outbreaks of typhoid fever were serious and of frequent occurrence and the mortality rate was 54.8 per 100,000. In 1923 the rate was 4.8. For the past three years there has not been an outbreak of typhoid fever chargeable to a public water supply under control of the Bureau.

(16) Consists of the following members of the Governor's cabinet :— the Secretary of Forests and Waters, the Attorney-General, the Commissioner of Fisheries, the Chairman of the Public Service Commission and the Secretary of Health as Chairman. The Chief Engineer of the Department of Health was elected by the Board as its Secretary.

(17) Under this authority the Bureau prepares permits approving or requiring the degree of treatment of sewage and quality of effluent to be produced.

(18) Under this authority the Board has jurisdiction over discharge of industrial wastes to the waters of the State.

(19) The resolution of the Sanitary Water Board for classifying streams is as follows :

" *Whereas,* The degree of pollution of the waters of the State varies widely from the pristine purity of a small stream flowing through a virgin forest to the grossly polluted stream draining a valley given over to intense municipal and industrial development, and

" *Whereas,* Such differences in condition and the present and probable future use of the streams must be recognised in determining the required degree of treatment of sewage and industrial wastes, and

" *Whereas,* The natural powers of streams to inoffensively assimilate and dispose of polluting matters by dilution must be utilised so far as compatible with the general interests of the public in order to establish a practicable and economical programme for stream control, therefore

" *Resolved,* That the waters of the State be classified as follows :

RELATIVELY CLEAN AND PURE STREAMS.

CLASS "A"

"Streams in their natural state probably subject to chance contamination by human beings but unpolluted or uncontaminated from any artificial source, hence generally fit for domestic water supply after chlorination, will support fish life and may be safely used for recreational purposes.

STREAMS IN WHICH POLLUTION SHALL BE CONTROLLED.

CLASS "B"

"Streams more or less polluted, where the extent of regulation, control, or elimination of pollution will be determined by a consideration of (*a*) The present and probable future use and condition of the stream; (*b*) The practicability of remedial measures for abatement of pollution, and (*c*) The general interests of the public through the protection of the public health, the health of animals, fish and aquatic life, and the use of the stream for recreational purposes.

CLASS "C"

"Streams now so polluted that they cannot be used as sources of public water-supplies, will not support fish life and are not used for recreational purposes, and also from the standpoint of the public interests and practicability it is not now necessary, economical or advisable to attempt to restore them to a clean condition; and further,

"*Resolved*, That all artificial pollution of Class "A" streams shall be prohibited and any sewage or industrial wastes on the watershed shall be treated to such a degree that the effluent shall be practically free from suspended matter, non-putrescent and disinfected and that recreational use shall not be sanctioned within prejudicial influence of waterworks' intakes, and further,

"*Resolved*, That the degree of treatment of sewage and industrial wastes discharged into Class "B" streams shall be determined for each particular stream or portion thereof after consideration of the general interests of the public and the economics of the particular case, and further,

"*Resolved*, That sewage and industrial wastes may be discharged into Class "C" streams, provided, however, that such discharge shall not create any public nuisance or menace to health."

DISCUSSION.

MR. J. K. HOSKINS (United States Public Health Service) said: Before discussing the very interesting address to which we have just listened, I desire to present to the Conference the greetings of the Public Health Service of the United States of America, which Department I have the honour to represent at these meetings. I am also delegated to convey to you the best wishes of the Conference of State Sanitary Engineers of the United States, an organisation composed of the chief sanitary engineers of the various States of our country.

The outline of the organisation and operation of the Ministry of Health, as just presented by the Assistant Secretary, is most instructive. The decentralisation of power by operating through the Local Authorities offers a happy solution to a most difficult problem in government.

In the United States this end is attained in a somewhat similar manner so far as health administration is concerned. The Federal Government had created the Bureau of the Public Health Service to have control over matters pertaining to public health, to conduct research dealing with the diseases of man, the nature of their propagation and spread, and to study the pollution of streams and lakes, and to co-operate with the States in the prevention of spread of epidemic disease. Each State exercises, within its borders, supreme power over all matters affecting the health of its inhabitants ; the Public Health Service has jurisdiction where the inter-State relationship becomes operative. Since disease knows no political boundary this arrangement has resulted in the establishment of close co-operative relationships between the Public Health Service and the State Health organisations. Advice and assistance are supplied where required and scientific research and field demonstrations conducted to ascertain and demonstrate practical methods of solution of the various problems in which the States are interested. The activities of the Public Health Service are many and varied, but in the main, in dealing with local problems, the object is to strengthen and assist the State Health Department wherever necessary to operate effectively under the powers granted by the State law-making body.

Dr. W. B. Mercer (M.O.H., New Zealand), expressed thanks to the Council of the Institution of Sanitary Engineers, and the Institution as a whole, for having allowed him, as a Medical Officer of Health in New Zealand, to attend this very important Conference. He would not have missed the addresses by Mr. Gibbon and Mr. Boulnois for anything, because they showed what had been accomplished by the English school in public health, which they in New Zealand had endeavoured to copy, though on a small scale as yet. It was a great thing for any of them from New Zealand to listen to such addresses. When he went back to New Zealand he would be able to tell his colleagues about this Conference, which, he hoped, if it did not become an annual event, would certainly be repeated at reasonable intervals. Discussing the interdependence of the sanitary engineer and the Medical Officer of Health, he said that the sanitary engineer might be able to get on without the Medical Officer of Health, but certainly the Medical Officer of Health could not get on without the sanitary engineer—or rather, the " sanitation engineer," which, he agreed with the President, was a much better term ; he, the M.O.H., would be as a ship without a helm. In conclusion, he again expressed his thanks, on his own behalf and that of his Department, for the privilege of attending the Conference.

Mr. T. Chalkley Hatton (Chief Engineer, Sewerage Commission of the City of Milwaukee, U.S.A.) then gave an illustrated description,

with the aid of lantern slides, of the activated sludge sewage disposal plant at Milwaukee.

(Details are given in Mr. Hatton's paper, printed on pp. 86-90.)

On the motion of the President, a hearty vote of thanks was accorded the authors of the papers, and the Conference adjourned.

WORDS OF WELCOME.

By THE RT. HON. JOHN WHEATLEY, *Minister of Health.*

The afternoon session, at which the President resumed the chair, was opened by the Rt. Hon. JOHN WHEATLEY (Minister of Health), who said he hoped that nothing in the nature of an address was expected from him because it would be sheer affectation on his part to pretend to be able to favour them in that manner, but he felt it was his duty as Minister of Health, and as representing His Majesty's Government, to look in at the Conference, if only for a few minutes, and to extend to it a few cordial words of welcome. He extended that welcome particularly to the people who were present from abroad, who had come to attend this Conference and give it the benefit of their opinions and experiences in the work under consideration. He had no doubt at all that the Conference would benefit by the knowledge and the views which the delegates from overseas would put before it. The question which was to engage its attention that morning was one which did not take into account or took very little into account, national frontiers. It was one of the great health problems which went to convince us, if anything would, that as human beings we were brothers with similar problems and similar enemies, and that we ought to co-operate in the interest of human civilisation in overcoming those difficulties. Those present who had come from other parts would have had to deal with different circumstances from those which confronted us in this country, for sanitary engineering was not merely a matter of knowing what particular result would be obtained from a particular piece of machinery, but it was knowing exactly the conditions in which those results might be secured, and it was by enlightening the Conference upon these matters that the overseas delegates would be able to add to the knowledge of this country. He hoped they would learn something from us. He thought he might be justified in saying that we in this country had not been behind the other parts of the world in the development of sanitary engineering. If one might take the death-rate of a country as an indication of the progress that had been made in sanitary science during forty years, we in this country had achieved something that was of enormous credit to us. He found that in 1874 the death rate in this country was 22.2 per thousand of the population, and that in 1923 this had been reduced to 11.6. That showed what our fathers had been able to do for us, and by doing that they had placed

on us an obligation of not resting content with their achievements, but of doing something in our day and generation which would redound to our credit as the progress they had made undoubtedly did to theirs. He might be challenged, of course, if he gave all the credit for the progress that had been made to the sanitary engineers. No doubt doctors would claim some of that credit, and, speaking as a representative of general social reformers, he would on their behalf like to claim some little credit for the progress made. There were things done so efficiently to-day, such as sewage disposal and refuse collection, that the average citizen almost forgot that they were done. He was only reminded of them when the rate collector came along. Then he was apt to grumble at having to pay the bill, but in the old days he would have been reminded of the manner in which this work was done by regular devastating epidemics ; and if he had to choose to-day no doubt the ratepayer would select the bills he had rather than those he had escaped from during the past half century. He hoped that in considering the papers that would be put before them the members of the Conference would remember how much human welfare depended on the manner in which they did their work.

Mr. J. S. Alford (the Chairman), moved a very hearty vote of thanks to the Minister of Health. He said the most casual reader of the daily newspapers would know that there was not a more busy or harassed individual in the United Kingdom than the Minister of Health, with the possible exception of the Minister of Labour. Mr. Wheatley had been put to some inconvenience to attend the Conference. His visit had been useful and helpful, and had put the official seal on the Conference work. In Pepys' Diary they would read that the Sovereign used to come into an adjoining building to that in which they were now sitting to heal by touch the disease known as the King's Evil. Many of the ancient powers of the Sovereign were to-day dispersed among his various Ministers, and that part of them which related to the healing of diseases by touch, so far as it remained, must have descended on the Minister of Health. It was, therefore, appropriate that Mr. Wheatley should have assured the success of the Conference by his presence. Speaking personally, he felt relieved of a great weight which had been pressing on his (the Chairman's) mind for some time past. About two months ago the Prime Minister in opening an exhibition of paintings, had made a speech. If he was correctly reported, he had said that man did not live by cleanliness, but by romance. When he (the Chairman) read this he thought it could not be the considered opinion of the Cabinet. He had said, " What is to become of the Sanitation Engineer ? " Now that he had heard Mr. Wheatley he knew that when the question came up before the Cabinet Mr. Wheatley would be the friend of the sanitation engineer and would stand firm for a mixture of cleanliness and romance.

The vote of thanks was heartily accorded and the Minister of Health briefly replied.

RECENT PROGRESS IN MALARIA CONTROL IN THE UNITED STATES.

By J. A. Le Prince,

Senior Sanitary Engineer, U.S. Public Health Service, Chairman of National Malaria Committee, Memphis, Tenn.

The first control measures were undertaken in Cuba in 1901 and were followed by the campaign at Panama, beginning in 1904. This work indicated that the flight range of the malaria mosquito (*Anopheles*) was more limited than that of some pestiferous mosquitoes, and that it was essential to determine the limits of flight range of the former ; also it indicated the necessity of means of control other than drainage and application of larvicides for use where drainage was not practical. It was thought that these two demonstrations would induce the public of the malarious sections of our country to undertake similar work, but such did not prove to be the case.

Until 1913 no communities in our country undertook malaria campaigns and during that year our federal health service received a small appropriation for malaria control investigations. It was thought advisable at first to determine the location and extent of our malaria prevalence and to induce the local communities to undertake work which would be of large benefit to them. This task proved to be more difficult than might appear and it soon developed that a most important part of the malaria control programme was to get the public to see the need of and seriously desire to have malaria eliminated. The communities first approached were doubtful as to the possibilities of economic malaria control, and it became necessary to obtain successful results before they were convinced. In some of the communities surveyed it was determined that the manufacturing industries were seriously affected financially by malaria among their working forces and though the managers were at first sceptical about possibilities of reducing malaria and financial losses, they were induced to take a chance and finance a campaign which they were

told would increase their profits and make their labour more efficient. Soon after operations started they both felt and saw the results obtained, while the local community officials waited to see how long the benefit would remain. The local public then became convinced that malaria control was possible and were persuaded to undertake and finance similar local campaigns. As federal government health agents were directing the work the public got the impression that the federal government should finance the campaigns, and it took time to make them see it was well worth while for them to undertake and finance the work themselves. Campaigns were thus started in eight of our states simultaneously with the field investigations that were being made.

Until our country entered the war none of our state health departments had any appropriations for malaria control, although in many counties of some States malaria was economically the most important of our controllable diseases. In some counties as many as one-quarter or more of the rural families had malaria.

When America went into the war, it was at once decided to locate many war camps and war industries in the malaria zone of our southern states, and our small malaria investigations' force consisted of five men. The camps and industries were located where most convenient irrespective of local malaria prevalence and topography favourable thereto. We knew that with the same malaria rate in our war camps as obtained in our two previous wars, we were due to have at our camps many thousands of malaria cases and five thousand deaths. Zones of protection were established around each cantonment, each war industry centre, and the nearest towns, and malaria control operations undertaken in these areas. The work had to be done well and rapidly, and while we were at it we controlled the pestiferous mosquitoes as well as the malaria conveying species. We were able to reduce malaria transmission at these centres to a practical minimum, and in place of the five thousand deaths in our enlisted forces from malaria we had but thirty-one, with a corresponding reduction of cases.

The towns near the cantonments were kept fairly free of pestiferous mosquitoes, and malaria in their suburbs was brought under control for the first time in their existence. Not only did the local people and the thousands of visitors see and feel what was going on, but the matter was fully explained in the public press. We used the war period as a means of getting the public to want what we knew they needed. Most of the cantonment towns are yet continuing their control measures. Immediately following these results the state health departments were practically swamped with requests for advice and help for malaria control work to be undertaken by other communities. This made it essential for our state health departments to undertake advisory and supervision work in their counties and led to establishment of malaria control divisions in the state health departments. At the present time most of our southern States have state appropriations for malaria elimination, and considerable progress is being made toward malaria control. For some

years the public of our country have had a strong desire for freedom from the mosquito pest, and at present are paying more than twenty-five million dollars a year for mosquito protection wire to screen their homes.

In connection with the control of the malaria-mosquito, we find it also advisable to eliminate the pestiferous species, as our public are as interested in nuisance prevention as in malaria prevention ; also the recent epidemic of dengue fever has aroused considerable additional interest in the elimination of the house mosquito (*Stegomyia*) which conveys this disease.

It takes a number of years of hard work to get the public to believe in malaria elimination. We must first get them to understand why we have mosquitoes and that they can be economically eliminated. That the support of the public individually is necessary to successful achievement. A common mistake that is frequently made in starting campaigns is to fail to fully advise the public as to what is being done, why it is being done and of the importance of their co-operation.

Ten years ago malaria was of frequent occurrence in the suburbs of our southern cities and in the smaller towns, while to-day many of these towns and cities are controlling their local malaria conditions and the number of such communities is constantly increasing.

As malaria is really a rural problem it is the agricultural population that is most seriously affected by the disease. Since the state health departments have undertaken this branch of sanitation, their propaganda is being systematically extended to the rural sections. The cause and means of prevention of malaria is being taught to the children in our country schools. Exhibit material is being shown at the annual county agricultural fairs, portable moving picture films are shown to rural audiences at churches and at open air meetings and the local rural press is being freely used. In many instances malaria control operations have led to the establishment of permanent county health organisations. These consist of a health officer, a sanitary inspector and a trained female nurse employed throughout the year. Such an organisation in addition to building up and maintaining the health status of the rural communities, can extend the malaria control operations and prevent neglect of maintenance work related to it.

Our federal health service is co-operating with the state health departments, studying their procedures, testing out modifications of control measures, making investigations and devising new control methods.

We find that engineering construction operations are responsible in our country, as well as others, for much of the Anopheles propagation near thickly settled districts. This occurs frequently in connection with construction of highways, railways, irrigation and impounded water projects, and could and probably would generally be corrected at relatively low cost if the supervising or consulting engineer only knew of the future damage he was creating. This matter has been taken up with all of our technical and engineering schools so that our future engineers will not make these same errors.

Three of our large railway systems are assisting in malaria control operations of the communities along the territory they traverse. They find it decreases the labour turnover of their forces, keeps the employees more efficient, reduces hospital costs and increases decidedly the freight revenue from the districts they serve.

The construction of large lakes for hydro-electric power development was formerly accompanied by marked outbreaks of malaria and numerous legal damage suits, but a study of these projects has enabled us to control these difficulties by fluctuation of water level, clearing, removal or control of floatage and propagation of top-minnows (*gambusia afinis*). This fish is also used in our farm stock ponds as a means of mosquito control, and is found to thrive and prevent mosquito production in wooden cisterns used for storage of drinking water-supply.

The use of Paris green thoroughly mixed with road dust, one part Paris green to a hundred of dust, and lightly broadcasted in a light breeze has proved to be much more economical as a larvicide for Anopheles larvæ than other larvicides previously used. It is more effective and practical where sufficient aquatic plant life is present to make oiling expensive and unsatisfactory. It will not kill other mosquito larvæ and when properly applied is harmless to aquatic life and farm stock that drinks the treated water.

Investigations are now being made with a view to reducing cost of malaria control and preventing its spread in localities where population is sparse and drainage operations not yet practical.

It is not intended to give the impression that our malaria problem is solved. We have a very large territory to cover, and our malaria is widely distributed. It is estimated to cause a financial loss exceeding a hundred million dollars a year. We have malaria work fairly well started in most of the States in our malaria territory, the interest in its control is increasing and the educational work that is being carried on will bear fruit in the near future. It is much less difficult to get communities and counties to undertake malaria control work now than it was a few years ago. It is inadvisable to carry on the work more rapidly than the public desire it and decidedly advisable to develop permanent public interest in what is being done. One of the biggest problems before sanitarians of all countries is to determine the best method of developing and maintaining permanent public interest in applied sanitation, and this applies also to malaria elimination.

The business and financial interests that will profit most largely by malaria elimination are the ones that are often difficult to convince, and yet when they once get interested will be our most useful agents in extending our operations.

The day has come when we should no longer have sources of malaria mosquitoes close to or in our towns, and it is the duty of the sanitary engineer and civil engineer to see that these sources of disease are permanently eliminated. Minor drainage as well as major drainage

is an engineering project and one in which sanitary engineers should and must take interest.

There are exceedingly few malaria situations that cannot be controlled, although it is at times the most difficult of our problems to so convince the public and sometimes even health officials.

In selecting a place for a malaria control demonstration a few years ago six communities were visited and five refused to even consider the project. Yet before the sixth community had been at work for a year, each of the other five made a request for advice and supervision as they had a changed viewpoint.

The sanitarians engaged in malaria elimination in our southern States meet once a year with the Southern Medical Association and the proceedings of the meeting are published by the U.S. Public Health Service at Washington, and available without cost to all malaria field workers and those interested in malaria elimination.

SOME SANITARY PROBLEMS IN THE MALAY PENINSULA.

By Sir Malcolm Watson,

M.D., C.M., D.P.H., Hon. L.L.D. Glasgow,

M. O. H. Klang, Federated Malay States.

When asked to read a paper to you, it occurred to me that I might refer briefly to some of the problems which confront the tropical sanitarian at the present time, or have done so in the past. The first is a water-supply problem ; the second a latrine problem ; and the others relate to the control of malaria and show how important the biological study of the mosquito vector is in designing practical measures for its control.

A WATER-SUPPLY PROBLEM.

The problem under consideration has arisen on an island in the delta of the Klang and Kuala Langat Rivers. The level of the island is below that of the spring tides, and cultivation is possible only by embanking the land, and draining it through tide gates.

Within ten feet of the surface of the soil, the water is brackish. Bores sunk in various parts of the alluvial land of the island and the mainland have failed to reach palatable water up to a depth of 200 feet. The Government Geologist holds out no hope of better results by going deeper. So the problem is to supply the population with water which shall be palatable and safe ; for I need hardly point out that in all tropical countries, where the native mind has no idea of what constitutes a safe water from a western standpoint, the risk of serious loss both of life and money is great, and is an ever-present responsibility to those entrusted with the care of a labour force.

When the population was small, and the land newly opened, shallow surface wells were sufficient. As larger areas were opened up, and the drainage was improved, to the great advantage of the land from the agricultural point of view, water became scarcer and scarcer, and finally failed entirely in even short periods of drought.

The supply was then supplemented by water caught from the roofs of the coolie lines, but this too was insufficient, even with the heavy rainfall of from 60 to 100 inches a year. For the southern Indian, like all who dwell in a perennial hot climate, insists on his daily bath, as well as water for cooking and drinking.

When both the rain water supply, and that from surface wells in the open land adjoining the coolie lines were found to be inadequate, large tanks were dug in land still covered by jungle. Two thousand acres were reserved for a water supply. Water was drawn or pumped from the tanks into water-tanks on trolleys, and railed to the various lines. Since the creation of the tanks in the jungle, there has always been some water available for the inhabitants, even in the severest droughts ; but even then the method of delivery was difficult and expensive, and the water not by any means free from possible contamination.

It was decided, therefore, to install a regular piped supply with a pumping and filtering station. This has been done, and an abundant and safe water supply is now available from the tanks.

As long as the rainfall was moderate in amount, the water supplied was clear ; for the water in the tanks was of good colour. With the heavy rains at the end of the year, the whole jungle area in which the tanks are situated became a continuous sheet of deeply coloured peaty water, which gained access to the canal connecting the various tanks with the intake pipe. The pulsometer filter had no appreciable effect on the colour ; although both lime and alum will clear the water, if supplied in quantity and given the necessary time.

As the problem stands at present, it is doubtful if the cement sedimentation tanks, which hold about 50,000 gallons, will be sufficient to clear the water before it passes through the filter. If so, then the proposal is to increase the height of the embankments round the tanks, and arrange for the water to be drawn directly from them, instead of from a connecting canal which will always be liable to flooding with peaty water. There is, of course, no doubt that in a short time the problem will be solved, and that an abundant supply of clear water will be available for the inhabitants of the island.

A SEPTIC TANK LATRINE.

On the island of which I have just spoken, the latrine problem has been very difficult of solution. The ground water is within a foot or two of the surface of the soil even at the driest time, and in a climate with so heavy a rainfall—two or three or more inches may fall in an hour—the ground is often water logged. In addition to danger from dysentery and cholera, the danger of ankylostome infection is always present ; for practically 99 per cent. of the Indians who arrive in Malaya from India harbour the worm, although, of course, comparatively few show much anæmia.

Deep pit latrines are, in such conditions, impossible. Shallow pits are not much better ; they are liable to flooding, and are at all times

full of water. As we know, too, such shallow pits are favourable for the growth and development of the ankylostome larva; and so are a danger to those using them. The danger, however, has been slight, for the Indian is little inclined to use these latrines, which in truth cannot be anything ut repulsive.

It has always appeared to me that if we are to induce the Asiatic to use a latrine, it must be one in which the fæces of the previous user disappears, if possible before his successor appears—e.g., into a deep dark pit, or where the fæces are flushed away within a moderately short time. With the institution of the piped water-supply on the island, it was possible to consider a septic tank latrine. The special problem was to obtain the necessary fall, for as I have said when there is heavy rain, the ground is practically water-logged and the drains are running full to the brim.

The plan, which I exhibit, shows how the problem was successfully solved. The latrine proper consists of a cement trough, flushed at short intervals. Between the two troughs for fæces is a trough of clean water for ablution purposes. The floor of the latrine is raised about a foot above the ground level.

The trough discharges into a septic tank of the usual type, situated entirely below ground level. This discharge, just below ground level into another tank filled with broken bricks and sand.

In heavy floods, the water flows back into this tank, but has caused no trouble with the septic tank proper.

This form of septic rank is becoming popular with the coolies. Its chief drawback is that it costs just over £1 sterling per head. But *if* it is used, I think it will justify the expenditure.

SOME MALARIAL PROBLEMS.

Over thousands of square miles in the Malay Peninsula, the control of malaria is to-day as much a part of the routine sanitary work as the supply of water or the removal of refuse; indeed in many places it is regarded as the most important sanitary measure and is supervised accordingly. Drainage and oiling are the two chief methods in use—apart, of course, from mosquito nets which are used by Europeans, Malays, and Chinese, but rarely if ever by the lower class Indians. It is not my purpose to give you in any detail the history of the struggle with malaria in the Malay Peninsula in the past twenty-four years. I can interest you more I think, by running through a few slides illustrating the practical solution of the various problems, and showing their relationship to and dependence on the habits of the different species of anopheles which carry the disease.

The first series show the measures to be taken in land which is undrainable, or drainable only through tide gates, or with a fall rarely exceeding one foot in a mile. I will show you a photo of a centrifugal pump at work draining an estate which could not be economically drained in any other way: because it is far from the sea, and even if

its outlet drain were cut through to the sea, the cost of the necessary gates and embankments would far exceed that of the method adopted. I will show you, too, a photo of tide gates—there are many varieties. One of the safest has an automatic gate on the outside and a screw-down gate in the inside, for use if the automatic gate fails to close. The photos, too, show the type of drainage necessary in flat land—it is open earth drainage.

Now all these methods are brilliantly successful in low lying land, and for this reason. The mosquitoes, which inhabit the low coastal lands, are essentially pool breeders. Water on such land, unless in the large streams and rivers, is practically stagnant. In search of its food, the larva comes to the surface, and moves from place to place on the surface of the pool as its fancy chooses. When alarmed, it dives to the bottom. When danger is over, it again comes to the surface. In small pools, there are few if any fish ; so it is rarely necessary to take cover. In larger pools, the larvæ either take cover among the grasses at the side, or in masses of floating alga or other aquatic vegetation. One danger the pool larva has rarely to contend with is a rush of water which would carry it within reach of fish and similar enemies. It has therefore developed no provision to meet such a condition, and so is entirely unable to exist either when its pool is dried up by a drain, or the pool is converted into a channel which is flushed out by heavy rains or invaded by fish.

In time the more enterprising mosquitoes went further afield or rather inland. They found delectable places in clear crystal streams, some of which contained fish, and all contained running water, often fiercely running torrents.

To some mosquitoes the advantages appeared to outweigh the disadvantages, and they developed structures and habits, which counteracted the disadvantages. In other words, they developed a larger supply of hooks on their tail bristles, than the pool breeding mosquito has. They acquired the habit, too, of swimming rapidly and immediately to the side of their breeding place, should they for any reason have dived to the bottom and again come to the surface. Instead of searching for their food, they hang on to the side of their homes, and allow the running water to bring their food to them. So firmly can they attach themselves that the torrent produced by a two-inch shower has little effect on them. Only prolonged rain, for a month or two on end, can wash out most of them—although even this is not the whole cause of the seasonal variation in the number of the species.

Now it will be evident, that although cutting a drain through a pool creates a current and other conditions which the pool breeding larva cannot resist, and which lead to its disappearance, a drain through, or the clearing out of, a stream, in which a stream breeding mosquito is living, causes no embarrassment to a stream breeder like *Anopheles maculatus.* Other species, less accomplished, are driven out by the draining of a hill stream ; not so *A. maculatus.* Nothing, except

subsoil drainage, oiling, or heavy shade will drive it out. Until one or other of these methods were employed, mosquito and malaria control, although brilliantly successful in the lower lands, was a failure, or worse in the hill lands. I said worse, because, until we understood the habits of the hill mosquitoes, our efforts sometimes increased rather than diminished the number of mosquitoes.

The photos illustrate some of the conditions found in hill land, and the methods employed to eliminate the mosquito.

As I mentioned in opening, malaria control is a routine in the Malay Peninsula. Tens of thousands of lives have been saved. In the City of Singapore alone, nearly 40,000 lives have been saved in the last eleven years by sanitary measures, of which the most important has been malaria control. For twenty years before the anti-malarial work was begun in 1911 a wave of malaria submerged the city annually and it raised the death-rate on an average in the month of May to a greater height than even the appalling influenza epidemic of 1918 could do. To-day the annual malarial wave has been so substantially reduced that it has lost its terror.

In conclusion I would remind you that all this has been possible through the work of Ronald Ross. With the discovery of the malarial parasite by Laveran, the problem was to find how the parasite passed from man to man. In vain men sought to advance. In literal truth a deep morass barred all progress. The genius of Ross discovered the way; yet I tremble as I think that but for his indomitable perseverance, generations might have passed with men still halting before an impassable swamp.

YELLOW FEVER PREVENTION WORK ALONG THE UNITED STATES-MEXICAN BORDER.

By R. E. Tarbett,
Sanitary Engineer, U.S. Public Health Service.

General mosquito control work, involving as it does drainage, diking, use of engineering structures and directing of labour, is essentially an engineering problem.

Yellow fever prevention as such, however, would appear to be somewhat outside of the field of the engineer since it has to do with the control of the production of a mosquito entirely domestic in its habits, whose breeding places will be found only in artificial water containers in close association with man.

The establishment of this prevention work on a permanent basis, however, involves problems of both an educational and engineering nature, problems which rightly fall to the engineer engaged in public health work.

While the methods involved in carrying on yellow fever prevention work are to a certain extent very similar to those in yellow fever control work, the former is much more difficult, although perhaps less nerve-racking than the latter.

During an epidemic, measures may be taken, with the full consent and co-operation of the general public, which are impossible under non-epidemic conditions. In preventive work, therefore, it is necessary to accomplish the results through educational measures tending to interest householders in the necessity of control work, with as little show of authority as possible. With a certain class of the population, there is a feeling that any attempt to dictate the manner in which a householder may or may not maintain water containers upon his premises is an interference with his personal rights and privileges. With the Mexican population, which constitutes a considerable portion of the population in the area where work is being carried on, it is necessary to change customs and habits formed through generations, the most important of which is the aversion to using water drawn directly from the tap. Apparently in their opinion water must be exposed to the air to be safe for use.

In order that the necessity for prevention work along the Texas-Mexican border may be better realised, it is necessary to consider conditions existing at present and compare these conditions with those existing in the past when yellow fever was a more or less frequent visitor to this section of the United States.

First let us consider briefly the question of yellow fever itself. Prior to the New Orleans epidemic of 1905, yellow fever epidemics occurred at intervals in the Gulf Coast states, having origin in the West Indies and Mexico. Since that time, however, the United States has not been visited by an epidemic. Two reasons may, perhaps, be given for freedom from this disease. First, the institution of control measures in endemic regions following the great work of Carroll and Reid in Cuba, in 1900-1902, and, second, the spontaneous elimination from endemic centres as outlined by Carter. (R.1.).

The disease has, however, continued in some endemic centres, particularly in the Yucatan Peninsula on the east coast of Mexico. Of this region, Gorgas, Carter and Lyster (R.2.) state "There seems good reason to believe that the Gulf Coast of Mexico was probably the original cradle of this disease in man and it may also be its last resting-place."

In 1903, a wide-spread outbreak of yellow fever occurred in the east coast states of Mexico, extending into the interior and entering the United States at Laredo, with a few cases as far north as the City of San Antonio. Active work was undertaken by the Mexican Government following this epidemic, and until 1920, with the exception of a few sporadic cases in the Yucatan Peninsula section, the country appeared to be relatively free from the disease. In 1920, however, another outbreak occurred throughout somewhat the same areas as did the 1903 epidemic.

During the period following the 1903 epidemic, yellow fever was undoubtedly present in the east coast states of Mexico, not in epidemic form, but perhaps in a mild unrecognised form among children.

Active work by the Mexican Government, the International Health Board and the larger oil companies had by the end of 1922 brought the disease under control, nevertheless, in the latter part of the 1922 season a few known cases occurred within eight hours' travel of the Texas-Mexican border, and one mild case, unreported, entered the United States.

It appeared that there might be the possibility of the disease again entering the United States in epidemic form, and that until it was definitely established that yellow fever was eliminated from Mexico, a potential danger existed which might at any time become real. Prevention work, therefore, seemed advisable, and such work was started in those sections on and near the border which appeared to be the most important.

The Texas-Mexican border, if we follow the meanderings of the Rio Grande River, has a length of approximately 1,700 miles. For the most part the areas bordering this river are undeveloped and very

sparsely populated. Along the lower sections of the river, particularly from the City of Del Rio, east, and in the river valley, the introduction of irrigation has brought about a considerable development, although there still exists in this section undeveloped, semi-arid regions.

From the standpoint of prevention, this lower region extending northward from the river, a varying distance, and including the City of San Antonio, appeared to be the important area, since it was reasonable to suppose that those persons who were most liable to be the means of introducing infection would remain within this area for a length of time, sufficient to complete the six day incubation period.

The district referred to has an area of over 26,000 square miles, and a population of approximately 475,000. Within the district the area of greatest importance is that lying between the Texas-Mexican railroad, which extends from Laredo eastward to Corpus Christi, and the Rio Grande River, an area of approximately 16,000 square miles.

In 1903 in this area there was a population of approximately 80,000 people, with but three small cities and of this population 67,000 were Mexicans or of Mexican parentage. To-day in this same area, there is a population of over 200,000, with seventeen cities of various sizes and of this population only about 90,000 are Mexicans, or of Mexican parentage. The City of San Antonio, lying to the north of Laredo, has increased from 50,000 to 180,000 in population, of which 30 per cent. are Mexicans or of Mexican parentage. In 1903 the area above mentioned was more or less isolated, there being no rail connections, except those existing between Laredo and San Antonio and Laredo and Corpus Christi. Transportation other than by rail in this district was necessarily slow and the spread of any possible infection nil. Rail connections to-day extend into the lower valley, but perhaps what is more important in drawing all sections into close proximity of one another has been the construction of highways and the development of the automobile. To-day, one may travel by automobile in as many hours as it formerly took days to make the trip.

In 1903 the demand for labour was almost exclusively confined to the few required on the cattle ranches, while to-day, thousands of additional labourers are required during the crop season in this area and this additional labour must be supplied from Mexico. This demand during the summer season has produced conditions which materially increase the potential danger of the introduction of epidemic diseases, namely through the illegal entry of Mexican aliens. Due to the character of the country this illegal entry can be controlled only to a very limited extent and during periods of labour demand, it is doubtful if over one-quarter of those aliens entering the United States enter legally through the port of entry, where they may be subjected to proper medical inspection.

The illegal entry of European aliens has also produced conditions tending to increase the potential danger, particularly with reference to the larger cities in the district. Due to the stringency of our present

immigration laws, smuggling of aliens would appear to be a well organised and profitable business, and one which it is not possible to control in its entirety.

As to the mosquito vector, *Aedes Aegypti*, it is only necessary to state that the conditions for the production of this mosquito are most excellent, and it is almost as prevalent as the more common domestic mosquito, the *Culex Quinquefasciatus*.

Public water supplies exist in only the larger of the incorporated communities, and in the greater part of these distribution systems are not sufficiently extensive to reach the entire population. We find, therefore, throughout the entire district, the original type of water distribution, namely, the water carrier with water barrels for storage of water at the various residences. The Mexican water carrier of the border is rather picturesque. A heavy two-wheel rig surmounted by a large cask, and drawn by one of the diminutive Mexican burros, the animal being all out of proportion to the size of the rig. In the more settled regions. the cask is equipped with a piece of red inner tube for use in filling barrels. Why red I do not know, but no other colour is used. In the small Mexican villages we find a rather primitive form of spigot made from a cow's horn. Water is obtained by these carriers from any available source. In the larger cities it is drawn from the city mains, while in the smaller places it may be from the river, the resacas, or from irrigation ditches.

In some of the sections, where rainfall warrants, rain-water cisterns are used to some extent, and in other sections, but to a relatively small extent, wells are used.

In 1923 the United States Public Health Service undertook to co-operate with the State Board of Health of Texas and with the various communities along and near the lower border, in order that such preventive measures as were necessary might be taken to prevent the possible entrance and spread of yellow fever. Notwithstanding the fact that the greater part of the population throughout the district was from sections of the country never visited in the past by yellow fever, and were rather loathe to believe that any potential danger existed, it was possible during the first season to obtain the establishment of preventive measures to a considerable degree. This was possible only through the institution of such measures as would not be of too great an expense to the communities and the individuals, nor too irksome upon the individual.

Not including the cities of El Paso and San Antonio, where work was being carried on, preventive work was instituted during 1923 in sixty-five cities and villages, having a population of from 150 to 32,000, with a total population of 175,000. In these communities there were 32,550 premises, and upon these premises were found 16,865 water barrels, 3,354 cisterns and wells, in addition to the usual collection of small containers of all types. None of these permanent water containers, such as water barrels and cisterns, were in any way protected

against the ingress and egress of mosquitoes, and the preliminary inspections showed a very large percentage to be breeding *Aedes Aegypti.*

Actual control work consisted in interesting the people in the necessity of eliminating unnecessary water containers and the protection of all the permanent containers, with routine weekly inspection of premises in order to eliminate breeding places.

In the protection of the more permanent water containers, if results are to be obtained quickly, it is necessary that the means taken be inexpensive as well as effective. The methods used for protection of water barrels consisted simply of having the barrels covered with a piece of fine mesh cloth held in place by a loose hoop. More permanent tops with spigots were recommended, but it was found that more satisfactory results could be obtained by simply covering with cloth, since the Mexicans had been through generations accustomed to dip water and dislike to use water, even when drawn from a tap on a city main. Barrels protected as above mentioned have rarely been found to contain mosquito life.

Wells, underground cisterns, and above ground wooden tanks, have been protected by the introduction of *Gambusia affinis.* The use of fish, however, in metal cisterns and tanks is not possible, due to temperature conditions, and these latter must be protected by proper screening, which is difficult, or routine oiling.

The work in the communities referred to has now progressed to such a stage that instead of there being over 16,800 water barrels in use, there are at present 5,450, or a reduction of 67.7 per cent., and of this number 84 per cent. are protected against the entrance and exit of mosquitoes. The number of cisterns, wells and tanks remain substantially the same, but of these over 60 per cent. are properly protected. Small containers still exist, but in a greatly reduced number, due in part to better care by the householder and to improved collection by the community. At present the status of the control work is such that it is very improbable that yellow fever could assume epidemic proportions were the disease introduced.

The last reports of inspection show an average of one water container producing mosquitoes to each sixty premises. Since *Aedes Aegypti* were not found in over 50 per cent. of the water containers having breeding, it would appear that the "Critical Number" referred to by Carter (1) is being reached.

In sections where mosquitoes are more or less prevalent, considerable difficulty is experienced in attempting to control one particular type, since to the ordinary individual no differentiation in the type of mosquito is made, and so long as discomfort exists, he feels that no headway is being made in the mosquito control, and that he should not, therefore, be made to take precautions upon his own premises. It is necessary, therefore, if we are to obtain effective control over one species of mosquito that the work must extend to other species in order that a relative freedom from mosquitoes as a whole may be obtained.

In addition to the *Aedes Aegypti* control work, every effort has been made to encourage the communities to carry on active mosquito control measures, and this work is meeting with considerable success considering the very short time which has elapsed.

In order that preventive work may be put on a permanent basis, it is necessary to very greatly broaden the activities and to secure contro over the malaria carrying mosquitoes, which are very prevalent in this section, and also over the pest mosquitoes, which are even more prevalent, together with educational measures, which will tend toward the establishment of full time active health organisations. With this accomplished, there will be established a zone along the border in which health work is carried on, which will not only prevent the entrance and spread of communicable diseases throughout the zone, but will also prevent and protect the State of Texas, and the southern section of the United States against the entrance of such diseases.

While the work has been primarily one of yellow fever prevention, the broader plan of work has not been neglected, and every effort is being made toward carrying out this plan.

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DISCUSSION.

Sir RONALD ROSS said that Sir Malcolm Watson had been working on this subject for a quarter of a century. The Americans had started almost simultaneously on anti-malarial work, and the results were to be seen in the three papers read to-day. During the whole of this quarter of a century we had been mapping out the habits of various kinds of mosquitoes, and studying what was to be done in various countries varying from those with thick jungle land to others with small vegetation, or even desert. Ismailia, on the Suez Canal, was the place where the French had got rid of malaria in 1902, and it had been an easy job—four men had done it. About the same time work had been commenced in America one also by Sir Malcolm Watson in the Federated Malay States. Sir Malcolm Watson had been struggling with the problem ever since, and he (the speaker) was delighted that he was to receive an honour from His Majesty the King, and had already received one from Glasgow University When he (the speaker) had begun to recommend mosquito reduction a quarter of a century ago, it had seemed quite easy to sweep

them all away. Gradually we had learned that it was easy in some places, but in others more difficult. In this campaign medical men wished to enter into the closest alliance with engineers. Most of those present were engineers, and he hoped that they would study the question of malaria if they had to do any work in the tropics. In fact, the doctors often had to hand this matter over bodily to the engineers. The great work in the Panama Canal had been very largely done by engineers, and so it would be in other parts of the world.

Dr. CARNWATH (Ministry of Health), said he would like to express on behalf of Sir George Buchanan Sir George's great regret at not being able to be present at the Conference. Sir George Buchanan had been very anxious to have the privilege of hearing these papers, and also of showing some small acknowledgement of the debt that Public Health Officers owed to sanitary engineers. The Officer in the Department upon whose advice they mainly relied, namely Colonel James, who had been Sanitary Commissioner in India, was unfortunately at present on a Committee of Investigation on this very problem in south-eastern Europe. Otherwise Colonel James would have been present. He (Dr. Carnwath) had very little experience of this work, although he had had the privilege of seeing something of what had been done in the southern States of America last winter, in Andalusia, Mobile and New Orleans. He had learned much of the vigorous and successful work there carried on. Here in this country malaria was hardly of economic importance, although we realised that from the point of view of the Empire it was probably most important. After demobilisation there had been a fear that malaria might become fairly prevalent in this country again, and measures had been taken to obviate this risk. The disease had been made notifiable, and Colonel James, who had had very considerable experience of the disease in India and elsewhere, had been looking after the matter.

It was interesting to note that the fear had not been altogether unjustified, because immediately after the demobilisation we had had a considerable number of cases of indigenous malaria in this country. Up to the present year we had had altogether about 489 indigenous cases. In 1919 for example there had been ninety-three indigenous cases in England. This number had fallen to thirty-two in 1920, to ten in 1921, to six in 1922, and only three cases last year; so that apparently the disease was gradually disappearing again. It was interesting to note that only one of the 489 cases had been fatal, but the opportunity had been taken to make some investigations at Hayling Island under the direction of Mr. Marshall, biologist, and Colonel James, and a good deal of work was being done to investigate some of the problems in connection with malaria. It was thought in England here, where the incidence of the disease was limited, probably some light could be thrown on the matter. It was from the international point of view that Sir George Buchanan was specially interested, and in that connection efforts were being made to ascertain the various factors that had been respon-

sible for the disappearance of malaria in some European countries. Malaria used to be quite prevalent in Denmark, Holland and this country. There was now an earnest investigation being made into the various factors that had led to the disappearance of the disease, in the hope that we might be able to get at that factor which was the most susceptible to control. In the case of malaria, as in the case of tuberculosis and other diseases, we were anxious not to be beating a dead horse. We wanted to concentrate on the particular factor which was most susceptible to administrative control, and it was hoped that the inquiry in south-east Europe would give us some information with regard to these factors.

Colonel W. CLEMESHA said he had very much enjoyed the paper. He thought that Sir Malcolm Watson's septic tanks could have been improved upon. He was greatly interested in these because the outline of the designs was probably the same as of those that had been made in Bengal. He would like to ask a question, Had there ever been what might be called a rough practical method of dealing with *Anopheles Ludlowii?* He thought the answer to that question was very important, because there was an enormous area of country in the tropics, especially in the Dutch East Indies, where *Ludlowii* was the carrier. Any cheap method of getting rid of that species would be of enormous benefit to the rest of the world. Officers in many parts of the world who were endeavouring to keep malaria down said they could do nothing when *Ludlowii* was the carrier. The cost of getting rid of it on radical lines was enormous.

Sir MALCOLM WATSON said this particular *anopheles* (*a Ludlowii*) was not found breeding when the mangrove trees covered the ground completely and shaded it over. It was found only when the mangrove was either partially cleared or fully cleared without the land being properly drained. Consequently you had two ways of dealing with the mosquito. You could either drain the land or cultivate your shade by preventing people cutting down mangrove trees and so getting a complete cover again. If, however, your mangroves were partially felled, there was no way of clearing out the mosquito except draining the land and cultivating it.

Mr. W. J. E. BINNIE (Past President), said he had had a curious experience whilst in the Malay Peninsula, and would like to ask Sir Malcolm about it. He had been one of a party that had gone up the Linggui River. It was very swampy, low-lying ground, and they had expected to be bothered with mosquitoes. They had had to branch off on the Semangar and get back to the civilisation through the jungle, but he had never come across a single mosquito. On the other hand on a beautiful range of hills the mosquitoes swarmed.

Mr. J. K. HOSKINS (U.S.A.) said he would like to inquire as to some of the details of the method of controlling mosquito breeding in rice fields. In the United States they were greatly troubled with the production of mosquitoes in certain rice farming areas. They had found in some rice fields that mosquitoes would breed, but in other fields immediately adjoining,

where conditions were as far as could be seen entirely similar, there would be no mosquitoes. He would be interested to know what progress had been made in the Malay States towards ridding the rice-fields of mosquitoes.

Sir MALCOLM WATSON said with regard to Mr. Binnie's question he was in himself a seeker after truth. He remembered going into a piece of jungle in the day time and catching about two hundred *anopheles* in a quarter of an hour. In addition to these there were four or five other species of mosquitoes in even greater numbers. A quarter of an hour in that jungle was therefore about as unpleasant as anybody could wish. He had gone into the same jungle at ten o'clock the same night and stayed for over half an hour and heard only two mosquitoes. He could not explain it. With regard to the malaria of rice fields that was practically the problem he had had in Assam. He thought it would be solved successfully, because as far as malaria was concerned the two species of mosquitoes which were the principal carriers were extremely sensitive to pollution. It was proposed to give them a small dose of oil. It was proposed to collect in drains the water as it came from the springs and out of the banks at the sides of the river valleys, and by dropping oil on to it, to give the mosquitoes water faintly tinged with oil. From his own experience he thought it would be found that while this would not control some of the species of *anopheles*, it would control the two dangerous carriers, *Anopheles maculatus* and *Anopheles minimus*. He would like to see further research carried out in rice fields, and he did not think the problem of malaria in them would be insoluble. He thought we should find some cheap method, such for instance as allowing the fermentation of tapioca or other vegetable matter in pools at the side of the rice-fields. He could not state what the final solution would be, but knowing the peculiarly selective tastes and habits of mosquitoes he felt sure we should win in the end.

Mr. L. JOHNSON (London) said he would like to ask if, in relation to the difficulty he had mentioned at the beginning of his paper, Sir Malcolm Watson had ever tried to chlorinate the water before active filtration. He (Mr. Johnson) thought it was commonly known that during the war the water supplied to the troops in France came almost invariably from contaminated sources. That water was nearly all chlorinated and made perfectly wholesome so that it was the cause of no illness. The chlorination destroyed all bacteria and vegetable spores in the water and so the water was rendered absolutely sterile. If in addition to harmful bacteria the water also carries suspended matter and is discoloured, sulphate of alumina in addition to chlorination and filtration would render it bright and clear. A brick of sulphate of alumina could conveniently be placed at the intake so that the exact proportion of alumina would be transmitted to the water.

Sir MALCOLM WATSON said that in this particular case the water came from uninhabited jungle, and there was no question of danger from disease. It was purely a question of the aesthetic quality of the water.

They wanted to give a beautiful clear water, and with the present pumping machinery and tanks five grains of alum and lime did not bring the precipitate down in time. It was a case of either keeping the peaty water out from the sources or increasing the size of the settling tank.

Dr. SCHARFF (London School of Tropical Medicine) said the words of Sir Malcolm Watson were my inspiration some five years ago to undertake anti-malarial work in the neighbourhood of Singapore. My work there followed most closely with those which he has just described and the good effects of subsoil drainage were equally inspiring. The need for a knowledge of engineering or for the close and sympathetic co-operation with an engineer is our most pressing need in anti-malarial operations in Malaya. I have no doubt that Sir Malcolm's words and the publication of his results will be a fresh incentive for others to follow in his footsteps.

Mr. A. J. MARTIN (Past President) said he knew no more triumphant vindication of the value of research than the papers before the Conference that day. The value of such research had been very forcibly brought home to him a few years ago in going through what used to be a death trap to the white man—the Panama Canal zone. Now it could almost be called a health resort. He believed it was an offence there to have eaves gutters, because these served as breeding places for mosquitoes.

Driving round Cristobal with the sanitary engineer, he noticed some large stretches of shallow water. He pointed them out to the engineer, who replied, " Oh ! that's all right : that water is salt. Mosquitoes won't breed in it." He had taken the opportunity of discussing that point with Sir Malcolm Watson, and he understood from him that certain species of mosquito would breed in salt water.

After passing through the Panama Canal he went to a place which used to be called the Graveyard of the West Coast. In 1848 half the population had been swept off by yellow fever : the cemeteries were the biggest he had ever seen. A year or two before he arrived they had had a case of yellow fever : they assured him it would be the last. It was almost ludicrous to think of the simple means by which this devastating disease had been swept away from a place where it had been endemic for generations. Unlike the mosquito which carried malaria, the yellow fever mosquito—*stegomyia*—was an affectionate domesticated creature ; it lived indoors in cisterns, water-tanks and similar places. Various means had been tried to get rid of it at Guayaquil. They got a small fish and put it in the water-tanks. The fish was quite good at swallowing the larvæ of the mosquito, but it was always throwing itself over the edge of the tanks. They had found another fish which was a success, it did destroy the larvæ and it stayed in the tanks. But the main resort was the compulsory covering of the cisterns. One morning when he was in his room a couple of inspectors had come in to see that the seal on the cover of the cistern over his bath was intact. By such simple means yellow fever had been stamped out. He had for ten years been preaching that education was the first step in sanitation, and certainly

the extermination of such diseases as yellow fever and malaria was no exception to the rule.

Dr. JAN SMIT (Amsterdam) said he had been for some years in the Dutch East Indies. The name of Sir Malcolm Watson was highly honoured there.

Mr. F. C. TEMPLE (Jamshedpur) said the question had been raised as to the effect of chlorination of water before filtration. He had tried it in the East with disastrous results, because it was impossible to get rid of the taste of the chlorine after the water had been chlorinated. No one would drink the water that contained the chlorine. The people had gone off to bad pools and ditches and drunk from them. There were bitter complaints even now if any trace of chlorine was found in the system. He agreed with Colonel Clemesha that Sir Malcolm Watson's septic tanks could be improved upon. He would like to ask Sir Malcolm Watson whether he had used any larvicides? At Jamshedpur, in order to reduce the number of mosquitoes they had tried drainage, but had not yet succeeded in clearing up the little pools, though they hoped to do so. They had been using crude carbolic larvicide and found it effective at a strength of one in 5,000,000,000.

Sir MALCOLM WATSON said the septic tank which had been adversely criticised was, he believed, a literal copy from the book, "Sewage Disposal in the Tropics," by a well-known authority. If it was not recognised he was afraid his engineer had made a mistake. With regard to the use of larvicide, the problem in Malaya did not seem at one time to offer much scope for that, especially for the larvæ that lived in running water. The idea of putting oil on running water had seemed at one time absurd to him, but after going to Panama, and seeing their oiling and their larvicide, he thought he had better try. He thought that in addition to oil he would have to use some rather poisonous substances. He had expected to go through a whole series of substances until he found something effective that would be a substitute for the expensive subsoil drainage. But he began with a mixture of kerosene and liquid fuel, a refuse oil; and the very first mixture, without any special poison or preparation, had given a 100 per cent. success. The method was now used extensively in the Malay Peninsula.

Mr. J. S. ALFORD (the Chairman) said he had not been concerned in any engineering work carried out expressly for the prevention of malaria, but he wished to refer to the increasing use of propaganda for the purpose of getting something done. This was referred to in Mr. Le Prince's paper. In America they were really expert in these things, but he rather doubted whether we were expert here. We might learn from America to use propaganda for the purpose of preventing malaria.

A vote of thanks was passed to the authors of the papers.

ELECTRICALLY DRIVEN CENTRIFUGAL PUMPS FOR WATER SUPPLY AND SEWAGE DISPOSAL.

By John Bergström,
Chief Engineer of the Municipal Waterworks of Stockholm.

During the last decade a number of large power plants have been built in Sweden, particularly by the Royal Board of waterfalls, in order to utilise the abundant supplies of water power. In this way electric power has been made available over extensive parts of the country and in almost all its towns the cost of such electrical energy is very reasonable, especially where the demand is great. This condition has of course influenced the arrangements of the water supply and sewage pumping stations, the more so on account of the electric power in most cases—particularly for the municipalities in the interior parts of the country—being obtainable at a lower price than steam power produced by fuel, generally coal. Now, electric power is almost exclusively used for new plants of this kind, unless for special reasons—as for instance heating purposes—a steam plant is needed. Oil engines are rarely used for regular duties, but are frequently installed as reserve machinery. Steam plants are also installed as stand-by units.

As a rule, for electrically driven pumping stations centrifugal pumps are used, since the efficiency of such pumps has been greatly improved, even for large heads. Piston pumps are used less frequently on account of the inconvenience of power transmission by belting or gears.

The advantages of centrifugal pumps over piston pumps are as follows :

(1) Centrifugal pumps are easily connected directly to electric motors.
(2) Centrifugal pumps have no valves, necessary priming arrangements are easily provided, and the lubrication is simple.
(3) The wear of parts and the consumption of lubricants is small.
(4) Electric motor driven centrifugal pumps require little attendance.
(5) The operation is smooth and the uniform movement of the water makes it unnecessary to use air-chambers.
(6) The dimensions of centrifugal pumps are smaller for the same delivery than those of piston pumps, and as centrifugal pumps have no exposed moving parts they need less space, which permits of smaller and cheaper foundations and engine room.

(7) There is no danger of overloading the motor nor of burst pipe lines on account of excessive water pressure if the delivery pipe is suddenly shut off, as centrifugal pumps raise the pressure comparatively little under such circumstances, on the other hand piston pumps cause great risks in this respect.

The variation of the water quantity at varying head or at varying resistance in the pipe line (when different quantities of water are passing through it), is a disadvantage with centrifugal pumps. Special attention must be given to this circumstance when planning new pumping stations in order to get suitable motors, and therefore the pumpmaker should always submit guaranteed characteristic curves of the pumps with his tender.

The water quantity delivered by a centrifugal pump not being constant in the same sense as the delivery by a piston pump—which is exactly determined by the number of strokes during a certain period—it is necessary to install water meters in order to control as closely as possible the variations of the water consumption which are of great interest in the water supply stations in finding eventual faults in the pipe-lines in time, faults not otherwise to be detected. Suitable water meters are at present to be had in the market, either with movable registering parts, such as the Woltmann meter, probably the best of this type ; or without movable parts, such as the Venturi meter, of which the Orivent meter is a modification. A combination meter embodying both these types consists of a Venturi meter combined with preferably an impeller type meter, through which a determined limited amount of the total water quantity passes and is registered. All of these meters may be provided with self-registering arrangements, thereby registering the total water quantity during a certain period or unit of time. By the aid of such meters the attendance of the working of centrifugal pumps offers no special difficulties.

It may be easily said that the reliability of the best makes of centrifugal pumps, as for instance the Zeta- and LW-pumps, generally used in Sweden, is now quite equal to that of piston pumps. The *initial cost* of a centrifugal pump with its electric motor is, of course, considerably lower than that of a steam-driven piston pump with due regard to the boiler plant. This is provided, however, that the connections with the main electric lines do not involve large expenses or difficulties. It is also considerably lower than that of an electromotor driven piston pump. In judging the economic relations, allowance must be made for the efficiencies of the different types of pumps and for the working conditions, and the generally somewhat lower efficiency of the centrifugal pump must be valued in money, capitalised and added to the *initial cost.* Allowance must also be made for the time of amortisation which might be somewhat shorter for a centrifugal pump than for a piston pump. The higher cost of the engine room and the more solid foundations required for the piston pump must also be taken into consideration.

At a recently completed extension of the pumping station of the municipal water works of Stockholm, careful investigation was made as to whether centrifugal or piston pumps should be used. It was in connection with furnishing pumping machinery for a regular delivery of about 50,000 m^3 a day and for the same quantity in reserve. The result was that two high pressure centrifugal pumps were installed, one for electric drive for regular use, the other one, steam turbine driven, in reserve. At the trials the capacity of the electromotor driven pump was stated to be 680 litres per second at a head of 62 metres and 440 litres at a head of 81 metres, all at a constant speed of about 990 revolutions per minute. However the motor was provided with a regulating resistance by means of which the speed could be varied and the water quantity brought down to about 380 litres per second. The total efficiency at the mentioned deliveries was 79.1 and 74 per cent. respectively.

A new filter pump, a motor driven centrifugal pump for 400 litres per second at a head of 10.7 metres, was simultaneously installed.

The electric motors are driven by three-phase alternating current of 3,200 volts, transformed from 20,000 volts. In regard to the reliability of the machinery, it was only after some hesitation that such a high tension was chosen, but during two years that the pumps have now been working, there have been no troubles in that respect.

The characteristic curves for the motor driven high pressure pump are shown by Fig. 1, p. 56.

For the old piston pumps at the same works, direct driven by horizontal steam engines, installed in 1904, the average coal consumption per cubic metre of water delivered is 0.28 kg., at the present coal price in Stockholm corresponding to 0.73 öre. Under equal conditions the new steam turbine driven centrifugal pump has a coal consumption of 0.24 kg., costing 0.63 öre. The consumption of electric energy by the motor driven high pressure centrifugal pump is 0.25 kw.h. per cubic metre or 0.61 öre at an average price for the electric current of 2.44 öre per kw.h.

The cost in coal or in electric energy per cubic metre of water is about the same for the new high pressure pumps and they are more economical in direct comparison than the old ones. The lower coal consumption of the new steam turbine pump might be partly attributed to the modern boiler equipment for 20 atm. steam pressure 325° centigrade steam temperature and provided with an economiser. Any comparison with modern steam engine driven piston pumps regarding working expenses has not been made, but such engines would have required four times as much space for the same capacity, necessitating an extension of the engine room, which was now not required.

In view of reliable operation a point to be considered was the difficulty of obtaining coal under certain conditions, involving the desirability of having access to a safe energy supply without neglecting the economical considerations. This question received a good solution.

The new installation also provided another very important advantage,

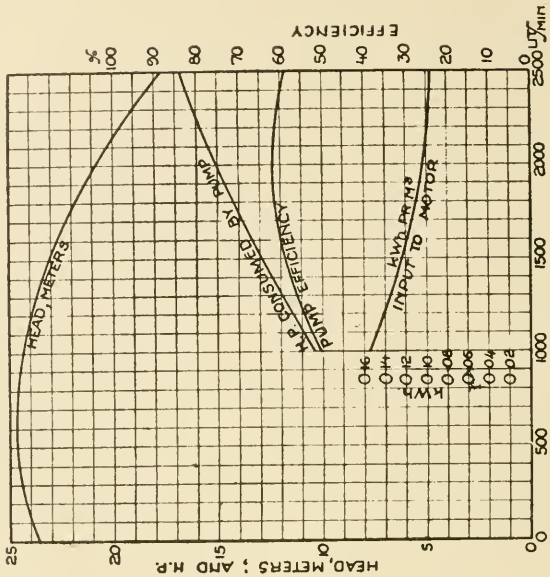


FIG 2

CENTRIFUGAL PUMP.

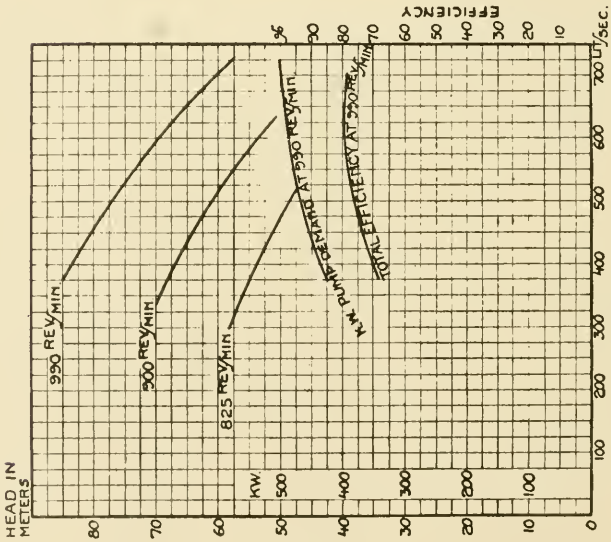


FIG. 1.

HIGH PRESSURE PUMP.

The new boiler is of the marine type and may, if necessary, be started and deliver steam at 20 atm. within a period of thirty minutes, and the turbine pump can be running at full capacity after a further fifteen minutes.

The property of centrifugal pumps to be quickly started has caused such pumps to be generally installed in Sweden as a reserve for fire service, especially in towns and communities where the ordinary water supply is so small that special arrangements must be made for fire service. In such cases where reserve power to the electric energy is considered to be necessary, petrol motors are extensively used because they are easily connected directly to centrifugal pumps and are quickly started.

Motor driven centrifugal pumps are the most convenient for boosting the water pressure in part of a pipe system, being easily fitted in between the existing pipes and capable of utilising the existing pressure. Installations of this kind, automatically operated either in combination with hydrophores or with the reservoir in a water tower, have been commonly used during recent years. In some cases centrifugal pumps are installed for continuous working for the same purpose without reservoirs or hydrophores, and this is feasible if the pumps have been dimensioned for the maximum supply and the necessary reserve is available. However, it might be only in exceptional cases and under special conditions that such an arrangement will work entirely satisfactorily. It also seems to be rather uneconomical, as the same pump must deliver both the minimum and the maximum supply but be dimensioned for the latter only. It is true enough that the motor becomes unloaded and the power consumption is reduced somewhat with a smaller water supply, but a certain loss must be taken into account, depending upon the length of the periods during which the supply is small or at zero. For automatic control and for distant control electromotor centrifugal pumps are exceedingly suitable, and probably at present, the only ones to be considered fit for pipe systems under pressure. The automatically operated pumps in combination with hydrophores will probably in the future reach an extensive use, since reliable and practical electric starting contrivances are now to be had. Small installations of this type are already used in great number and a proposition has been worked out for the supply of 600 cubic metres a day at a hospital.

Characteristic curves for a motor driven centrifugal pump installed in a pipe system for continuous work are shown in Fig. 2, p. 56.

For smaller deliveries from wells, 10 or 20 litres per second, however, piston pumps may be used advantageously, offering no mechanical difficulties. It is solely an economical question which system should be preferred. Where the suction head is very large, piston pumps are more reliable, centrifugal pumps as a rule not working well when the suction exceeds 6 or 7 meters.

Sewage pumps are a somewhat different class of machinery. As a rule the head is low but the water quantity all the larger. For this purpose centrifugal pumps have been used since long ago. There are certainly

other types of sewage pumps running, but in Sweden, centrifugal pumps are at present the only ones used. The sewage pumps for ordinary service are generally electromotor driven and principally arranged in the same manner as the water supply pumps. However, they are provided with very large passages, both in the casing and in the impeller, to give free passage to solid matters that manage to enter the pumps. Only pumps the interior of which is easily accessible for cleaning are used. Therefore, the pump casing should always be directed horizontally and, if necessary, provided with sufficient inspection holes. The efficiency is a little inferior to that of the water supply pumps, but in cases where not only the sewage but also the rain water must be pumped, centrifugal pumps are indispensable on account of the facility in starting and the possibility of combining with automatic contrivances.

In a résumé of the above it may be set forth that centrifugal pumps at present have attained such a degree of development as to be on a level with piston pumps as much from an economical point of view as in regard to safe working even at large heads, especially if they are arranged with electric drive. In some cases only electromotor driven centrifugal pumps may be considered suitable. However, this does not exclude that piston pumps under certain circumstances may be preferable. That is a matter for close examination in each case with regard to the given conditions.

FRICTION OF SEWAGE SLUDGE IN PIPES.

By William Clifford,
Manager and Chemist, Sewage Works, Wolverhampton.

Considerable interest has been manifested lately in the possibility of utilising sewage sludge in the liquid state for agricultural purposes. One of the obstacles to the wider adoption of this method of sludge disposal has, no doubt, been the want of information relative to the amount of frictional resistance to be allowed for; information expressed in lbs. pressure per square inch, or as so much "head" per 1,000 feet, rather than as viscosity or friction coefficients.

In what follows, it is proposed, (*a*) to give certain data, obtained with a 4 inch pipe line; (*b*) to obtain indirectly a value for the kinematic viscosity of average sludge; (*c*) to indicate the relative frictional values of sludges with differing water content; (*d*) to discuss other data; and (*e*) to give a table showing the pressure gradient for different sized pipes.

(*a*) The pipe line referred to is used for conveying ordinary sedimented sewage sludge; it consists of wrought iron welded tubes, 4 inch internal diameter, with conical socket and spigot ends, which allow considerable latitude for change of direction. The pipes are laid for the most part on the surface of the ground and not to any regular gradient, and the direction changes in passing from field to field.

The necessary "head" to overcome the resistance is provided by compressed air, the pressure varying with the length of the pipe line, the level of the outlet, the water content of the sludge, and the rate of discharge.

Temperature would, no doubt, have an effect, but this was not noted.

Generally the pressure was adjusted to give a rate of discharge about 13 cubic feet per minute; this corresponds to an average velocity of 2.5 feet per second.

The details relating to seven positions of the pipe line are given below.

Table I.

Length of Pipe line in feet.	Static lift in feet.	Air pressure in lbs.	Equiv. Head in feet.	Friction Head in feet.	Excess Length over A.	Friction Head over A.	Friction Headper 1,000 ft.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A... 99	22	22.5	50	28	—	—	—
B... 690	32	34	75	43	591	15	25
C...3900	12	55	122	110	3801	82	21
D...2520	73	77.5	173	100	2421	72	30
E...1770	55	55	122	67	1671	39	23
F...2700	56	67.5	150	94	2601	69	25
G...3750	78	85	189	111	3651	83	23
					Average	..	24.5

It will be seen from Table I. that there is considerable variation in the lengths of the pipe lines, and the height of the outlet above the middle of the sludge ram.

The air pressures recorded in column 3 are averages and are taken to represent pressures for average sludge.

The equivalent head, column 4, represents the figures in column 3, multiplied by .45, which is equal to the pressure per square inch of a sludge weighing 65 lb. per cubic foot.

Column 5, shows the pressure drop, in terms of "head," due to friction, and in order to eliminate the effect of a number of bends, valves, and junctions, at the inlet end, the shorter length of pipe line (A.Z) is deducted from the others to form column 6 and the corresponding pressure or friction head is deducted to form column 7.

The loss of head per 1,000 feet is given in column 8; the average of the six values is 24.5 feet. This may also be stated as a pressure drop of 11.025 lb. per square inch per 1,000 feet. With pipes laid to regular gradients, the friction loss would, no doubt, be slightly less.

(*b*) The resistance to the flow of water has been the study of hydraulic engineers and others since the time of Poiseuille; the results are usually expressed in one or other of the well known formulæ, of which Chezy's ($V = c\sqrt{m.i.}$) is representative; that is, in terms of the average velocity of flow, hydraulic mean depth, hydraulic gradient, and a constant.

The viscosity of the liquid is not taken into account except so far as it affects the loss of head and is merged into the constant or the indices of the factors on the right hand side of the equation.

The work of Osborne Reynolds (1883) and of Lord Rayleigh (1889) who enunciated the general law of resistance for homogeneous fluids, since fully established by Dr. Stanton and his co-workers at the National Physical Laboratory, has thrown a new light on the subject.

It does not follow that the law which holds for homogeneous fluids, will hold for sewage sludge.

The Rayleigh law may be stated in the form of an equation:

$$R = \rho V^2 f(V d/\nu) \text{ - - - - - } 1.$$

where R is the resistance per unit area, V is the velocity ρ the density, and f is a function of the variable Vd/ν: ν being the kinematic viscosity of the fluid, and equal to the viscosity divided by the density.

For pipes $R/\rho V^2$ becomes $m.i.g./V^2$.

So that 1 may be written:

$$m.i.g./V^2 = f(V d/\nu) \text{ - - - - - } 2.$$

By plotting $m.i.V^2$ against $f(Vd/\nu)$ on logarithmic paper, Dr. Stanton obtained for water and oil a characteristic curve, and the interesting point for the present purpose is that the values of m.i. and V are known for the 4 inch pipe line, g being the gravity constant.

Putting in these values,

$m.i.g/V^2 = .01052$, which corresponds on the Stanton curve to

$$f(V d/\nu) = 794.$$

This gives a kinematic viscosity (ν) .001055 in feet, second units, or taking density of average sludge at 1.051, an absolute viscosity of .0012 in feet lbs. seconds units, i.e., 1.1148 in c.g.s units. A solution of glycerine and water, containing 85.5 per cent. of glycerine has a viscosity comparable to this, at a temperature of 20° C.

As the kinematic viscosity is the connecting link between the several factors, it is desirable to have a more direct method of determining its value. With homogeneous liquids this is done by means of standard viscometers, but the nature of sludge precludes the passage through a capillary aperture. An indirect method, to be described later, has been tried.

(*c*) The above value for the kinematic viscosity of average sludge gives no indication how the friction would vary with the varying water content. It is known from the observed pressures, with the 4 inch pipe line, that watery sludge, with only 3 per cent. or 4 per cent. of solids, differed very little from clean water, and that as the solids increased beyond 10 per cent. the pressure increased rapidly.

This experience is confirmed by noting the time of efflux of sludge from a modified viscometer with an efflux tube $\frac{5}{16}$ inch internal diameter and $5\frac{1}{4}$ inch long*. Fig. A, p. 62.

The results are shown in the subjoined table and graphically in Fig. B, p. 63, where similar results for Syracuse sludge are plotted.

TABLE II.

Moisture content Per cent.	Time of efflux of 8,000 c.c. in seconds.
100	44.5
95.3	6
93.8	48.9
91.6	57.6
88.9	114.5

The sludge was first passed through a domestic mincer, and the observations made at 20° C. From three to five runs were made, and the average taken.

(*d*) The proposal to pump sewage sludge through a pipe line, and the paucity of information on the subject, led the engineering staff of the Syracuse Intercepting Sewer Board, to try to obtain data from which definite conclusions could be drawn, as to the frictional resistance of sewage sludge. The writer is indebted to Mr. Glenn D. Holme, Chief Engineer to the Board, for a copy of the report, and permission to use same.

Briefly stated, (1) an attempt was made, somewhat on the lines of Dr. Stanton, but under adverse conditions, to determine the pressure drop in a selected length of a 12 inch diameter sludge main at Toronto, by means of a differential U tube manometer. The results were admittedly not satisfactory, and no definite conclusion could be drawn. (2) A number of experiments were made to determine the viscosity of sludge, or rather a factor (*f*) depending on the viscosity. A viscometer of the torsion type was tried without success, then one of the efflux type, with a large container, after the Engler model, and an efflux tube 5/16 inch diameter and $5\frac{1}{4}$ inch long. This was standardised against standard Engler and standard Saybolt viscometers, with water and oil. The times of efflux with different sludges agree fairly closely with those given above.

* This instrument was made similar to one described in the report mentioned above, under section (*d*).

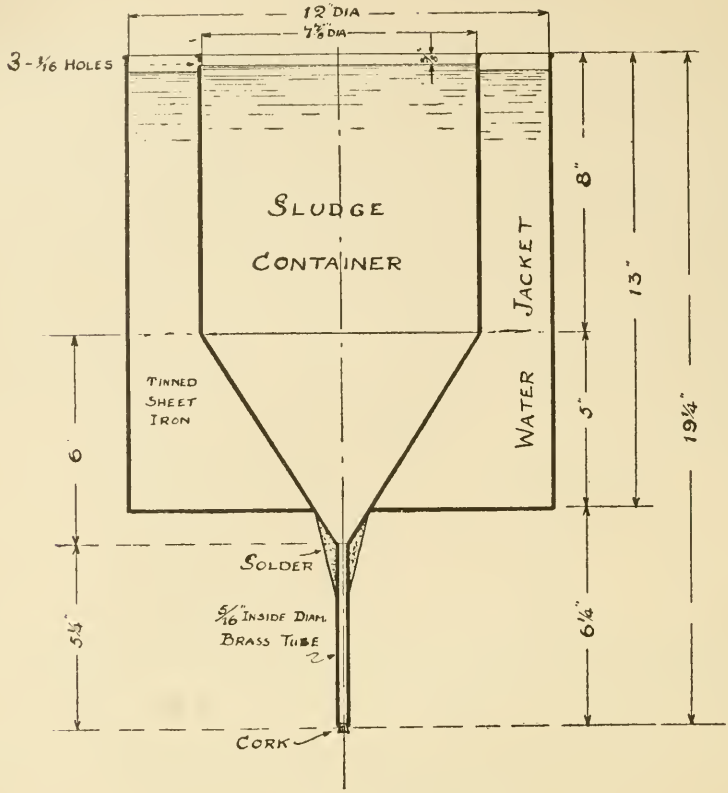


FIG. A.—SLUDGE VISCOMETER.

A friction factor is finally obtained, and by means of a formula the friction head or pressure drop per 1,000 feet is computed.

The following figures are taken from Table No. IX, of the report:—

TABLE III.

Friction of Sludge in 12 inch pipe at a velocity of 5 feet per second.

Water Content Per cent.	Friction head per 1000 feet in feet.
100	6.94
98	7.09
96	7.41
94	8.67
93	9.30
92	10.08
91	11.03
90	11.97

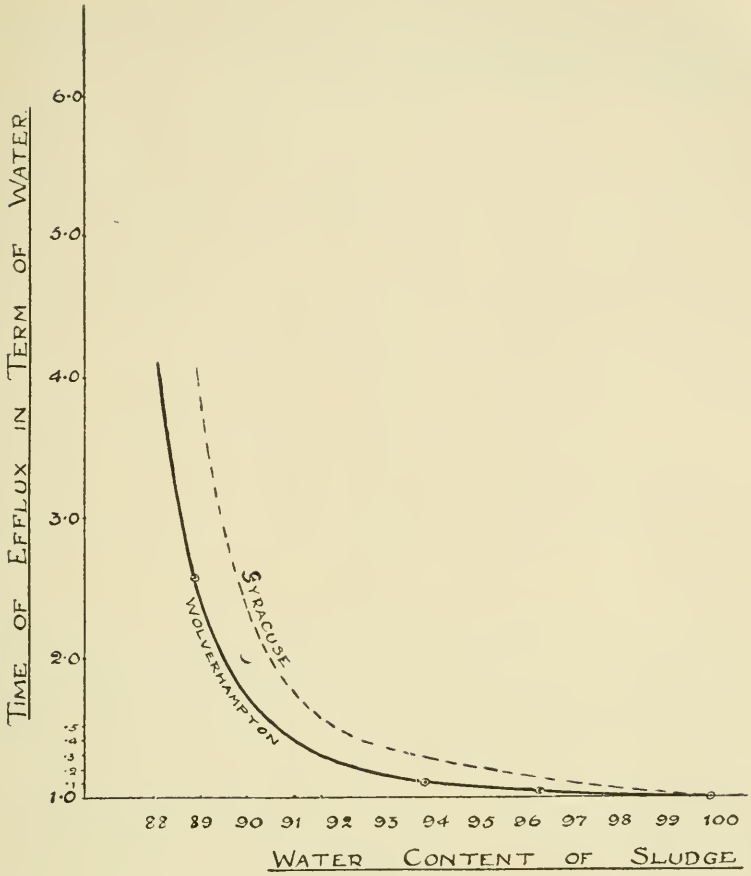


FIG. B.—RELATIVE VISCOSITY OF SLUDGE.

It will be seen that the result for 90 per cent. sludge is low (20 per cent.) compared with that deduced from the kinematic viscosity obtained above.

The variation of the efflux time with the water content is very similar to that given in Table II. See Curves.

Friction of paper pulp stock. As evidence of the marked effect of a small amount of solids on friction, in pipes, a curve supplied by the Buffalo Pump Company, Buffalo, N.Y., shows graphically the rapid increase in friction as the solids increase from 2 per cent. to $4\frac{1}{2}$ per cent. The writer of the report notes that " the data is not in accord with our sludge pumping tests or observations."

The following table, based on the data obtained with the 4 inch pipe line, is given as a first approximation, of the probable values of friction head under the conditions stated.

TABLE IV.

Based on kinematic viscosity (ν) = .001055 and use of Dr. Stanton's curve.

Diameter of pipe, in inches.	Average velocity feet per second.	Friction head, per 1000 feet.
4	2.5	24.5
4	3.5	32.9
4	5.0	46.6
6	2.5	10.3
6	3.5	14.3
6	5.0	29.2
9	2.5	4.6
9	3.5	10.1
9	5.0	21.5
12	2.5	3.6
12	3.5	8.1
12	5.0	15.0

A comparison of the friction losses with water in pipe lines with that obtained from the kinematic viscosity relationship, indicates that the former is more than twice that of the latter; it would therefore appear probable that any value of the kinematic viscosity of sludge, obtained by viscometric methods, would require a modification of the function Vd/ν.

For practical purposes, and until more accurate data are available, the friction head or pressure drop for 90 per cent. sludge per 1000 feet of pipe line, may be taken as approximately one and a half times that of water. Ample allowance should be made for valves, bends and junctions, and a further provision for those gritty sludges which appear from time to time. The average friction head from all sources, of four sludge mains in use, is about four times that due to water flowing in straight lengths of asphalted cast iron pipes, under the same conditions of diameter and average velocity.

The information relative to the Bradford main has not been included in the average. The conditions are exceptional; the low water content, the greasy nature of the sludge, and the method of ejecting air at intervals into the main. It would appear that this sludge flows with little more friction than water.

The information relating to the various sludge mains in use, tabulated below (Table V.) has been supplied by the respective engineers to whom my thanks are due. The friction head represents the friction losses from all sources. In general the shorter the pipe line, the greater the relative loss due to valves, bends, etc.

TABLE V.

Place.	Diam. in inches.	Length in feet.	Average Pressure lb. sq. in.	Discharge c.f.s.	Aver. Veloc. f.p.s.	Water Coat. %	Level Orifice feet.	Friction Head per 1,000 ft.
Birmingham ..	12	21,000	50	1.33	1.70	90	0	5.29
Glasgow	9	32,736	70	.57	1.29	88	15.5	4.75
Bradford.. ..	8	21,800	60	1.09	3.12	80	-45	8.18
Davyhulme ..	10	3,960	45	1.52	2.79	89	32	17.17
Wolverhampton..	4	Various	Various	.22	2.5	90	Various	27.9

DISCUSSION.

Mr. J. S. ALFORD (the Chairman) said there was practically nothing in Mr. Bergström's paper indicating that there was present to his mind the idea that there was any difference between pumping water and sewage. That difference was very substantial in his (the Chairman's) opinion, and painfully present to his mind from actual experience. He did not think pump manufacturers in this country realised how great the difference was. One frequently had guarantees offered under public tender which were based upon water. A number of manufacturers hoped to cover all their troubles by assuming a liquid of a specific gravity of 1.05, but that, in his opinion, was insufficient. In a rough and ready way he divided sewage that had to be pumped into three classes. First there was the sewage which had been passed through a screen with mechanically moved rakes. A closed impeller could be used with such sewage without any difficulty. Then came the sewage of which there was a great deal in this country, which had been passed through screens, usually vertical, with bars from one to three inches apart. These screens were lifted from time to time, and cleaned by an attendant. They would let through a certain amount of fibrous matter, and for such sewage, in his opinion, it was not desirable to use a closed impeller. In the case of an open impeller the efficiency depended among other things, upon the clearance space between the moving impeller and the casing; as soon as that became enlarged the efficiency fell. That could be attended to by providing the pump with renewable sideplates. A third

kind of sewage was that which had not been screened at all. Such sewage had been successfully pumped by one particular make of pump well known to them all, but he did not know up to what size that pump was made, or whether the larger pumps were satisfactory. So far as he knew, we still wanted for the pumping of large quantities of unscreened sewage something we had not yet got. He had been rather disappointed by Mr. Bergström's not referring to the non-overloading type of unshrouded impeller. Above all things it was necessary to a sewage works manager to have a pump which would require a minimum of attention, which would work smoothly and enable him to lead a comfortable existence in reason, rather than have from 2 to 5 per cent. more theoretical efficiency which as a matter of practice he did not always get.

Referring to Mr. William Clifford's paper, the Chairman said that if they looked at it they would see that it broke fresh ground. He was in sympathy with Mr. Clifford's statement that it did not follow that a law which held for a homogeneous fluid would hold for sludge. Sludge was not homogeneous and could not be made so. Practical experience showed that as the solids increased beyond 10 per cent. difficulties increased rapidly.

Mr. Harrison P. Eddy (Boston, U.S.A.) said that with reference to Mr. Bergström's paper, the centrifugal pump was very largely used for lifting sewage in the United States, especially in the newer installations. It was of particular advantage because of its automatic possibilities. In small stations, and even in very large emergency stations, centrifugal pumps were operated automatically without any attendants, or, perhaps, in stations of extreme size, with the attendance only of a common labourer. It had happened in the City of Boston a few years ago, when the large centrifugal pumping station to deal with storm water had been left entirely alone, that through some electrical mishap the transformers had given trouble when there was no one there. Since that time one labourer—not an electrician nor an engineer—had been kept at the station simply to telephone the superintendent if he discovered anything wrong, or, under certain specific conditions, even to throw out a main switch. According to his (Mr. Eddy's) recollection that station had a capacity of upwards of 150,000,000 U.S. gallons per twenty-four hours. The vertical shaft pump was used quite generally; an interesting illustration of this had occurred this spring. It had been recommended to a city that for an emergency drainage pumping station direct connected motor-driven horizontal pumps placed at the bottom of the well be adopted. It was pointed out that this would be considerably less expensive, and that the danger of flooding the motors which were to be in a dry well would only be due to the breakage of a casting. It had been felt that the hazard from electrical difficulties of the vertical shaft unit were much greater, because in the United States, if a vertical motor of such size—75 h.p.—was burned out, it generally meant rewinding the motor, or building a new one, which took considerable time, whereas

a horizontal shaft motor could be procured almost immediately. The city officials had felt that they would rather pay the additional price for the vertical pump and motor, and assume the hazard of electrical difficulties, because they had felt that the criticism due to flooding of the motors, if the unexpected and improbable bursting of the pipes should happen, would be so great that they did not care to take the chance.

Speaking of Mr. Clifford's paper, Mr. Eddy said this was of extreme interest and value. He (Mr. Eddy) had not had the opportunity of going over the figures, and therefore could not discuss the subject from a purely technical point of view, but desired to point out that work upon it was being done in the United States. The Sanitary Engineering Division of the American Society of Civil Engineers had had a Committee at work upon it, Mr. Holmes, to whom Mr. Clifford had referred, being the Chairman of that Committee. The first series of experiments that had been tried in the United States were under Mr. Holmes's direction —actually they had been performed at Toronto. Unfortunately the results had been practically negative, as was pointed out in Mr. Clifford's paper, due to the almost insurmountable difficulties in making the tests. Another series of tests last year had produced similar unsatisfactory results. Mr. Clifford referred to the case of Syracuse, N.Y., where the sludge had to be pumped some two miles for disposal. At Chicago the plant for the treatment of the sewage by activated sludge for the North Side portion of the Sanitary District provided for the pumping of the sludge sixteen miles through a force main. This would be dilute sludge because it would come from the activated sludge process. Information such as Mr. Clifford presented was needed; and they were greatly indebted to him for this pioneer work.

Mr. Fuller (U.S.A.) said that in the waterworks field in America there had been a growing use of centrifugal pumps, but there were decided limitations to the electric drive, particularly where the water was not stored in substantial quantities under pressure sufficient to serve the cities. He had in mind the interruption of electrical pressure, which had proved under these circumstances severe in some instances. The general discussion as to the use of electric motors for various pumping requirements had shown that where electric pumps could be used in connection with steam driven pumps there was a safety which was not found in those circumstances where motor driven pumps alone were used. He had had occasion in several cities to study relative costs, and found as a rule that steam pumpage was rather cheaper than electric current; but facilities for resisting the mishaps that came when the current went off quickly were under control to an extent not the case five years ago. He thought there was a growing use of motor driven centrifugal pumps in connection with large water supply projects. In Canada, where coal was expensive, and electric current readily procurable, they were used to a great extent, supplemented in most instances by Diesel engines. In regard to the use of centrifugal pumps for sewerage projects, he thought that almost without exception projects that dealt with 25,000,000 gallons

of sewage or less a day had been recently of the motor driven centrifugal pump type. He thought there had been in recent years a decided step in advance taken by the manufacturers of centrifugal pumps. Facilities for making repairs, guarding against stoppages and getting openings much larger than formerly, all showed that real progress had been made, and perhaps, to an extent, that progress was not greater than was to be found on this side of the Atlantic. His own feeling was that the use of the centrifugal pump was growing more and more important each year.

Mr. C. F. Beckenn said with reference to Mr. Bergström's paper, it was satisfactory to note that in Sweden the practice adopted for sewage installations as regards pumping plant was very similar to our practice in this country.

In sewage pumping, owing to the amount of gas which was liberated by the various kinds of sewage to be dealt with, which often included refuse from tanneries, chemical works, and the like, it was extremely important that the pumps be so located as to be below the level of the sewage—that is to say, the liquid should run into the pump by gravity. It was absolutely essential where the pumps were started up automatically by means of a float operated switch. The usual practice was to arrange vertical pumps driven by vertical motors, but if for some reason horizontal sets were proposed these should be arranged if possible in a water-tight chamber below the sewage level.

It was important to remember that if there was any vacuum on the suction side with the tendency to form gas the vacuum caused air to be liberated in the eye of the impeller, and this was fatal to the satisfactory working of a centrifugal pump.

Mr. Eddy mentioned that in the States they preferred horizontal electrically driven sets because of the difficulty of getting satisfactory vertical motors, but in this country many motor builders made a speciality of the vertical type of motor, and they were quite as satisfactory as the horizontal type and equally reliable in running.

The Chairman mentioned three matters which called for special comment. One was that open type impellers are the best for certain sewage work—two, that renewable parts necessary to the maintenance of efficiency should be arranged for—three, overloading of motors on low heads.

With reference to these points, if the impeller was made in the shape of a barrel or drum, and the openings round the impeller were so arranged that the liquid was thrown out in a rearward direction to the rotation, a reactive turbine effect was set up by the impeller which assisted the prime mover, and as a sequence if the head was reduced, such as was often the case as a result of storms, more water was thrown out rearwardly and more power returned to the prime mover; and the consequence was that this class of pump would work with constant power whatever variation took place in the lift against the pump.

This also effectually got over the difficulty of fine clearances and the necessity of renewable parts to maintain the efficiency. In fact, at

Faversham, where there had been five of these pumps at work for over ten years they were rather more efficient at the present day than they were when first installed—showing that the efficiency has been fully maintained over that period.

In dealing with ordinary sewage it was important to remember that the ordinary centrifugal pumps should not be installed for duties of less than about 15,000 g.p.h. on account of the narrow restricted orifices in the impellers tending to get choked up. There were one or two classes of pumps made for dealing with small quantities, but these have the disadvantage of being rather low in efficiency.

For dealing with rough sludge and forcing it on to the beds very satisfactory results had been obtained from a simple form of three pronged steel impeller which would pump practically anything dealt with in this class of liquid such as large stones, etc. ; and one of these had been working many years with complete satisfaction at the Walsall Corporation Sewage Works.

Mr. Geo. A. Wigley said in reference to Mr. Bergström's paper that it would appear that electric motor driven pumps were employed so extensively in Sweden on account of the particularly favourable position in which that country is placed in possessing a liberal and cheap supply of electric power. In other parts of the world where such conditions did not obtain, other sources of power, such as gas engines, oil or steam engines might be more advantageously used.

Regarding the priming of centrifugal pumps, this was usually a simple matter when clean water was to be dealt with, and a foot-valve generally sufficed ; but if sewage or sludge had to be pumped, foot-valves were often unsatisfactory, and priming was effected either by steam or air pressure ejectors or by means of auxiliary reciprocating air pumps.

Very large centrifugal pumps were sometimes evacuated by means of a small centrifugal pump, arranged to force one or more streams of water through the nozzles of a suitably designed ejector. The action was similar to that of an ordinary steam operated air ejector but actuated by water pressure instead of steam.

He quite agreed that very small centrifugal pumps should never be used for pumping sludge. A reciprocating pump was the better type of pump, not only on account of its higher efficiency, but because the reciprocating type was better able to move a temporary obstruction in the pipe line.

The remark made by the Chairman to the effect that manufacturers, when tendering for sewage or sludge pumps, often specified a limiting figure of 1.05 sp. gr. for the sludge, might be explained. In cases where it was not possible for engineers adequately to describe the consistency, nature, viscosity, and sp. gr. of the sludge to be dealt with, manufacturers, having no positive data to work upon, were forced to include some figure : 1.05 or 1.1 sp. gr. as the case might be, merely as a limiting condition to determine the terms of the contract.

Mr. Clifford's paper dealing with the frictional loss of head and the viscosity of sewage sludge was interesting and opened up new ground.

However, from experiments which had been made with crude oils and other viscous fluids, it would appear that once the viscosity was known, the loss of head for any particular pipe line could easily be calculated, as the laws relating to the quantities involved are known.

Some doubt arose as to whether sewage sludge could be considered as a truly viscous substance and whether sewage chopped up in the manner described in the paper would give the same result as the sewage in bulk. Moreover, according to Mr. Clifford's experiments, sewage of the same water content, taken from different localities, did not give equivalent results in his viscometer.

The following expression, giving the frictional loss of head for a pipe line carrying viscous oils, had been deduced from data given in a report of the National Physical Laboratory dealing with the viscosity of certain crude oils.

$$P = \frac{T.\ Q.\ \delta.}{11.\ 9.\ d^4}$$

Where P = pressure drop in lb. per square inch for 1,000 ft. of pipe line.
T = Standard Redwood Viscometer reading, time in seconds.
Q = Gallons per minute flowing through pipe.
δ = density, i.e., sp. gr.
d = diameter of pipe in inches.

The absolute viscosity of Redwood's Standard Viscometer was given by :—

$$\eta = \left(0.0026T - \frac{1\ 715}{T}\right)\delta.$$

Where η = absolute viscosity.
T = time of outflow in seconds.
δ density.

For the Redwood Standard Viscometer T = 386 for η = 1.0 and this proportionality held good for all valves of T exceeding 100.

The pressure drop could therefore be expressed by :—

$$P = \frac{32.4\eta Q\delta}{d^4}$$

and was thus directly proportional to viscosity, to rate of flow and to density, and inversely proportional to the fourth power of the pipe diameter.

COMPARISON OF STANDARD VISCOMETERS.

For η = 1.0	δ = 1.0.	Redwood Standard	= 386 seconds.
		Redwood Admiralty	= 44 seconds.
		Saybolt Universal	= 455 seconds.
		Saybolt Furol	= 46 seconds
		Engler Time of Efflux	= 680 seconds
		Engler Specific	= 13.33 degrees.

The above values were not correct for very short times of efflux, where the viscosity was approximately that of water.

Mr. J. W. Cameron said that in dealing with centrifugal pumps for small quantities, say ten to twenty litres per second, the quantity should bear a certain relation to the head, and if the width of the impeller for a given quantity came out less than about one-tenth of the radius of the runner, the efficiency would not be very good. For smaller quantities, if the width of the impeller came out less than that, he thought that the reciprocating pump was better from the point of view of efficiency. With regard to Mr. Clifford's paper, it was found in dealing with viscous oils that the friction varied directly as the velocity if the velocity was less than the critical velocity. Of course, one might get one class of oil, being very viscous, and the friction might vary as the velocity, and one might get another class of oil where the friction varied as the square of the velocity. Yet the friction loss for the two fluids would be the same, one varying as the square of the velocity and one varying as the velocity.

Mr. A. J. Martin (Past President) said that he felt a certain responsibility for Mr. Clifford's paper, as he had suggested to him that a paper on this subject would be interesting. He would like to congratulate the author on his ingenious method of arriving at the proportional friction of sludge, viz., by means of a viscometer. Obviously it was an exceedingly difficult and uncertain matter to obtain such data by means of small scale trials, but this method seemed to meet the case very well indeed—with certain limitations. He did not think it was a good thing to have to mince the sludge and so to a certain extent change its physical character. It seemed to him that the need for this could be avoided by working on a larger scale, which would admit of the use of an orifice capable of passing sludge in its ordinary condition. This should give more reliable results. He would like to ask whether the viscosity of sludge depended merely on its water content, or whether it was affected by other conditions? For instance, would the viscosity of a 90 per cent. sedimentation sludge be the same as that of an activated sludge containing 90 per cent. of water? Mr. Watson, in a conference at the Institution of Civil Engineers a few years ago, had given some particulars of his experience in piping sludge which had been subjected to a prolonged period of digestion, and Mr. Watson said that he was surprised at the ready way in which this comparatively thick material flowed. He had attributed it to the gas produced by digestion, pointing out that the minute bubbles of gas between the particles of sludge acted as so many ball bearings.

Mr. Eddy had referred to the work carried on by the Sanitary Engineering Section of the American Public Health Association. Co-operative work of this kind was of the greatest value, and unless we in this country took heed to our ways we should find ourselves very much behind American engineers. No branch of engineering could progress without research, and if research was to be dependent on the leisure, initiative and means of individuals we should not go very far. Our American

brethren had set us an exceedingly good example in resorting to team work for solving their engineering problems. He hoped we should not be content to admire them from a distance, but that we should follow their example, and in particular get some data on this important subject with which Mr. Clifford had dealt. He himself was an unrepentant believer in the application of sludge to land, and he viewed with considerable misgivings the resort to de-watering in all cases. In such conditions as we had in this country he was convinced that we usually did better to pump our sludge in a wet state on to the land than to attempt to reduce it to a dry form. Mr. Clifford had rendered great service to the community by pumping sludge on to surrounding farms at Wolverhampton and also by giving data for estimating the pipe friction.

Mr. Harry W. Taylor (Newcastle) said he would be very pleased if Mr. Clifford could tell them what kind of pump he had found most suitable and satisfactory in pumping sludge at Wolverhampton. He supposed they had all encountered this difficulty and that the pump makers were waking up to it at last. A year ago he obtained quotations for a centrifugal pump made by a well-known maker, to raise sewage sludge alone, not unscreened sludge, but the stuff out of the detritus tanks. This firm had supplied an engine and pump, but it was now found that a very much more powerful engine was required to do the work ; they had estimated for five horse power, but probably nine or ten would be required. It appeared that the friction of sludge must be a great deal more than that of water. He would like to ask if anyone present had any experience in pumping sludge with the " unchokable " or " stereophagus " pumps ?

Major C. Harold Heathcote, referring to a remark by the Chairman, viz., " an open type of impeller appeared to him to be necessary when pumping unscreened sewage," stated that after very careful experiment lasting over a term of years, the enclosed type of impeller with a specially constructed port had been found to be a perfect means of dealing with unscreened sewage. As a proof of this pumps of this description were running daily and for long periods on mixtures containing large pieces of rag, bundles of hair and other stringy and fibrous matters without suffering any trouble from choking. Referring to the question of a speaker as to whether anyone present had had experience of pumping heavy sludge in a satisfactory manner, he referred to a six inch " Unchokable " sludge pump supplied two years ago to the Leeds Corporation. This pump has been working continuously on heavy sludge, delivering it to a head varying from ten feet to forty feet and is giving great satisfaction. The efficiency of this pump is from 40 to 45 per cent. This continued over a period of twelve months will compare very favourably with pumps giving a higher efficiency but subject to stoppage by reason of choking.

In regard to the statement made by more than one of the speakers that in their opinion no pump smaller than a five inch or six inch could be relied upon to pass unscreened liquid, he wished to inform the Con-

ference of the case of Kiveton Park Urban District Council near Sheffield, where a three inch horizontal "Unchokable" pump was installed on a six inch main and had for eighteen months pumped the raw unscreened sewage of the district without the pump choking once.

Mr. L. JOHNSON wrote: the President had been good enough to invite comments from any member of the audience who was interested. He (the writer) had been greatly interested in the paper and would have thanked Mr. Bergström for it had he been present. It would be found that if only the cost of power was considered in driving centrifugal pumps, no one would ever buy them, and as centrifugal pumps were now almost entirely replacing reciprocating pumps, it shewed that this comparison by itself was not of any value. The pumping conditions on the Rand were, he believed, more severe than in any other country, and it was now an established fact that the mines were giving up the use of reciprocating pumps, although from all records the actual cost of current expended in pumping was greater. In a recent comparison it was found that the cost of power for a reciprocating pump was .289d. per 1,000 gallons pumped 100 feet, whilst for a centrifugal pump it was .321d. per 1,000 gallons pumped 100 feet. Nevertheless in that particular mine they gave up reciprocating pumps and adopted turbine pumps. A centrifugal plant with motor and starter complete cost 40 per cent. of a reciprocating plant. The weight of the centrifugal equipment was seventy pounds per gallon pumped per minute, whilst that of the reciprocating equipment was 350 lb. per gallon pumped per minute. In one case the excavation for centrifugal plant was 8,000 cubic feet and cost £200. For reciprocating plant of similar capacity the excavation would have been 55,000 cubic feet, costing £1,375. In the case of one of the mines they had before the turbine pumps were installed three throw pumps which had together twenty-four rams working, and they had to replace thirty rams per month to keep these going.

He would instance a turbine pump which was erected in these mines and put into commission in April. It was pumping 750 g.p.m. against 2,800 feet. Just before Christmas an inspection was carried out, all the parts being removed from the pump, and the inside was found to be in perfect condition. Wear was very difficult to detect, but in one or two places it was found to be less than 1/2,000th part of an inch.

To obtain such results it was, of course, necessary to look after the water, and it had been found on the Rand that it paid to spend money on looking after the water to get it into proper condition for pumping, and to use turbine pumps even though they took slightly more current rather than to use reciprocating pumps. In a turbine pump, if the matter in suspension was kept fine enough, it was capable of passing through the clearance inside the pump, because there was no metallic contact, whilst in the case of a ram pump, whatever solid matter there was in the water, and however fine it was, it was bound to be forced in between the ram and the packing, and part of the current was used in grinding down the rams. The result was that mentioned above, namely, the need of

putting in on the average one ram a day, which means that the pump had to be shut down and out of commission for a considerable time, which in turn meant that much more pumping plant had to be available. The fine matter in suspension in the water was settled out in specially arranged settling tanks with a great number of long weirs in the form of troughs over which the water had to flow in a very thin film before it reached the suction sump. It had been found from actual practice that fine matter in suspension settles very quickly to a depth of within ⅛ of an inch from the surface, but below that depth the settlement was very slow. If therefore the water could be arranged to flow over a sufficient length of weir so that the height over the weir is say only 1/32nd part of an inch to 1/16th part of an inch, there was very little risk of any solid matter getting into the pump. If the water was acid, it was generally neutralised with carbonate of soda, and he knew one mine where this was done at the cost of 2.6d. per thousand gallons, and the mine authorities found that it paid them to do it even at that price.

If all the factors were taken into account and users were prepared to pay the price for a properly constructed turbine pump it would be seen that pumping could be done much more cheaply by this type, otherwise reciprocating pumps would not have been replaced by them.

Mr. F. C. Temple (Jamshedpur) said he had tried to pump sludge from a septic tank by a two-inch centrifugal pump through a rising main which he thought was about 1,700 feet long. It was, he thought, twenty feet rise and the main two and a half inches diameter. The pump would not work at all. For the last three years he had been pumping crude sewage by centrifugal pumps up a height of 150 feet and a distance of some 7,000 feet. The sewage was pumped to the top of a hill where there were 1,000 acres of irrigable land. It was the first activated sludge plant to run on a practical scale in India.

Mr. Beckenn said, with regard to sludge pumps, he would like to refer the Conference to the old pump at Walsall. It consisted of a three branch steel impeller of the open type. It had been running for at least ten or twelve years with all sorts of dirt, lumps, fabrics and anything else, and it had been perfectly successful.

A vote of thanks was passed to the authors of the papers.

ACTIVATED SLUDGE PLANT, WITHINGTON SEWAGE WORKS.

By Edward Ardern,

Consulting Chemist, Rivers Department of the Manchester Corporation.

In this communication it is proposed briefly to describe an activated sludge unit recently installed at the Withington Sewage Works of the Manchester Corporation, and to include a short account of its performance during the nine months it has been in commission, together with a statement of the capital outlay involved and power required for its operation, running cost, etc.

DESCRIPTION OF PLANT.

The plant occupies a total area of approximately 1,450 square yards, aeration chambers (overall) 1,200 square yards, and settlement tank and measurement pond 250 square yards. It consists essentially of an aeration tank of total water-holding capacity of approximately 325,000 gallons, and a settlement tank, the capacity of which is approximately 88,000 gallons.

AERATION TANK.

The aeration tank, 180 feet long by 60 feet wide overall, is divided longitudinally to form two independent aeration chambers for the treatment of sewage, situate one on each side of a common central channel for the return and re-aeration of the sludge.

Each aeration chamber, 177 feet long by 20 feet wide, capacity 145,000 gallons, is divided by two longitudinal walls, with portholes suitably placed, to provide an aeration channel 530 feet long, 6¼ feet average width, and approximately 7 feet deep (water level).

Cross baffle walls, each with 1½ by 2 feet openings, fitted with deflectors, are constructed at intervals of 35 feet (average) along the whole length of the aeration channels.

The sludge return and re-aeration channel, 160 feet long by 6 feet (average width below water level) by 5½ feet deep (water level), capacity approximately 35,000 gallons, is similarly provided with cross baffle walls.

Aeration is effected through lines of diffusers placed alongside the inclined footings of the divisional walls on one side only of the channels.

The diffusers are each 3 feet by $4\frac{1}{2}$ inches (overall), so that their total area is approximately one-seventeenth of the aeration tank area. The ratio of actual diffusion area to total tank area is approximately 1 : 23.

An overhead system of air pipes is provided, and the air admitted to the diffusers by a series of down pipes, one to each diffuser. Valves are arranged on the air mains, so that the tank may be sectionised so far as air supply is concerned. In addition, each down pipe is fitted with a needle and orifice control for securing uniform air distribution.

SETTLEMENT TANK.

The settlement tank is a deep pyramidal tank with four pockets, 36 feet by 36 feet by $21\frac{1}{3}$ feet deep from water level to the apex of the pyramids. A 24 inch pipe to convey the mixed liquor passes from the outlet of the aeration tank to a central distributing chamber. The central distributing chamber is in communication with four Clifford inlets arranged over the centre of the pyramidal pockets.

Provision is made for the discharge of the deposited sludge by hydrostatic head through 6 inch pipes into a small central sludge channel communicating by a 15 inch pipe with the re-aeration channel.

The sewage enters the plant through a small mixing chamber into which is discharged the return activated sludge, and thence passes to the aeration chambers ; the mixed liquor ultimately discharges over cills into a narrow shallow lateral channel prior to passing to the settlement tank.

The sludge returning from the settlement tank after traversing the whole length of the re-aeration channel is lifted by the combined effect of two air lifts, working in series, into the mixing chamber previously referred to.

The mixing chamber and narrow shallow lateral channel are common to both aeration chambers, and the arrangement is such that if necessary the flow to one or other of the aeration chambers may be stopped, or either aeration chamber may be emptied without placing the whole plant out of commission.

The effluent leaves the settlement tank over a periphery cill and passes through a measurement chamber prior to its discharge into the main effluent carrier.

The surplus sludge is removed through a valve in the floor of the re-aeration channel, and passes through a 6 inch pipe to the general sludge well, where, if required, it may be densified before being lifted by compressed air and delivered through the existing sludge pipe track into trenches on the land area.

AIR SUPPLY.

Provision has been made for an ample supply of air, both for the old and new units, by the installation of two new type air compressors,

each capable of compressing approximately 700 cubic feet of free air per minute.

These compressors are each driven by 30 h.p. electric motors.

Meters are provided for the measurement of electrical units consumed and the volume of air employed.

The total expenditure on this plant, including air compressors of sufficient capacity to operate the new unit and the existing unit, which has been in operation during the past 7½ years at this works, amounted to £11,774 18s. 3d., of which £7,144 8s. was expended on constructional work, and £4,630 10s. 3d. on equipment inclusive of the provision of the above-mentioned air compressors, air meters and flow recorders.

OPERATION OF PLANT.

The sewage dealt with in this plant receives preliminary screening and treatment in detritus tanks whose gross water-holding capacity is equal to 40 minutes of the dry weather flow.

The plant was first filled with sewage on 28th August, 1923, when one-half of the unit was brought into use. Subsequently the other half of the aeration chambers was put in operation and the whole plant gradually brought into full commission.

The greater part of the month of September, 1923, was occupied in "building up" the necessary supply of fully activated sludge and since then the plant has remained in continuous operation, apart from a week's stoppage in November, to allow the level of the outlet cill of the settlement tank to be raised some 10 inches.

The percentage of sludge in the aeration chamber, measured by volume after one hour's settlement, has varied from 10 to 20 with an average of about 15 per cent.

During the period covered by this paper, viz., October, 1923, to May, 1924, inclusive, the plant has treated an average flow of 1,423,000 of screened and detritus free sewage per day, at daily rates varying from 800,000 to 2,860,000 gallons.

Calculated on the gross water-holding capacity of the aeration and sludge re-aeration chambers, the average detention period (without any allowance for volume of sludge present is equal to 5.4 hours, varying from a minimum of 2.6 hours to a maximum of 7.75 hours.

Correspondingly, the detention period in the settlement tank (calculated on combined volume of effluent and sludge in circulation) has varied from 35 minutes to 1 hour 30 minutes, with an average of 1 hour 10 minutes.

No difficulty has been experienced throughout this period in obtaining effluents of high quality thoroughly stable and well clarified, with suspended matter of less than 3.0 parts per 100,000 and whose bio-chemical oxygen demand is well below the limit of 2.0 parts per 100,000, recommended as a standard by the Royal Commission on Sewage Disposal.

A summary of the analytical returns showing the results of treatment is given in the table printed on p. 79, together with the quantity

of sewage treated, and the volume of air employed (inclusive of that required for the operation of the return sludge air lifts) in terms of cubic feet free air per gallon of sewage treated.

The volume of air employed has varied very considerably dependent on the strength and quantity of sewage treated, from a minimum of 0.35 cubic feet free air per gallon to an occasional maximum of 2.0 cubic feet free air per gallon of sewage treated, with an average consumption of 0.92 cubic feet free air per gallon of sewage treated: the normal working air pressure being about 4.0 lb. per square inch.

During March and April, an excessive air supply was employed, owing to the fact that the two new compressors were in use, consequent on the failure of a smaller old unit, which is now being replaced by a modern type of some 400 cubic feet per minute capacity. For this reason, the average air consumption for the period reported upon is somewhat higher than need be anticipated in the future.

The surplus sludge which, without any preliminary densification, has amounted to approximately 2.4 per cent. of the flow treated, has been dealt with by trenching into land on the works, or has been conveyed through a pipe track on to farm land or market gardens adjacent to the works.

Carefully controlled efficiency trials of the two new compressors installed at these works have demonstrated that their overall efficiencies (motor and compressor) measured from the switchboard are respectively 50.4 per cent. and 54.9 per cent. of the theoretical measured at 4.0 lb. pressure, calculated on the assumption that theoretically 0.016 b.h.p. is required to compress 1.0 cubic feet of free air to 4 lb. pressure.

With this average efficiency the h.p. required for the operation of the plant has been equal to 19 b.h.p. per million gallons of sewage treated. As stated previously, a slight decrease in the average power consumption may be anticipated in the near future.

During periods of heavy rainfall, when the plant has been operated at the maximum rate, the h.p. required has been as low as 8.0 b.h.p. per million gallons of sewage treated.

It is probable that an average of 18 b.h.p. will meet the requirements of this plant and at 0.7d. per unit, the approximate prospective price of current, the cost of power for operating the plant is equal to 18s. 7d. per million gallons of sewage treated (average flow).

The installation of this unit has not necessitated any extra labour either in the engine room or out of doors, and therefore the cost of attendance can only be estimated, and any such estimate manifestly will be governed by the size or effective capacity of the plant, inasmuch as one man could equally well take care of plants many times the capacity of the present unit. The actual attention required on the plant itself is very little, and, apart from the discharge of surplus sludge and its disposal, is mainly concerned with the taking of records in relation to rate of flow, volume of air employed and electrical power consumed.

ANALYTICAL RESULTS EXPRESSED IN PARTS PER 100,000.

Month.	4 hours oxygen absorption.		Free and saline ammonia.		Albuminoid ammonia.		Nitrite. Effluent.	Nitrate. Effluent.	Biochemical oxygen demand. Effluent.	Putrescibility. Effluent.	Daily flow million gallons.	Air consumption cubic feet free air per gallon.
	Sewage.	Effluent.	Sewage.	Effluent.	Sewage.	Effluent.						
1923.												
October	3.17	0.61	1.63	1.69	0.64	0.135	0.015	0.20	0.80	0/24	1.74	0.85
November	2.53	0.57	1.54	1.50	0.50	0.13	0.015	0.31	0.76	0/24	1.95	0.69
December	3.23	0.59	1.90	1.80	0.72	0.14	0.015	0.27	0.87	0/25	1.63	0.66
1924.												
January	3.04	0.61	1.87	1.86	0.63	0.13	0.015	0.21	0.83	0/23	1.52	0.67
February	3.34	0.63	2.54	2.44	0.72	0.15	trace	0.19	0.90	½/24	1.09	1.16
March ..	4.54	0.67	3.14	2.97	1.06	0.17	trace	0.17	0.86	0/24	1.10	1.51
April ..	4.76	0.74	2.54	2.41	0.83	0.165	0.02	0.20	1.00	0/22	1.17	1.35
May ..	3.64	0.70	2.11	2.10	0.72	0.15	0.03	0.20	1.00	0/19	1.18	1.01
Average	3.53	0.64	2.16	2.10	0.73	0.145	0.015	0.22	0.87	½/185	1.42	0.92

In considering the low power requirements of this plant, it must, of course, be borne in mind that the sewage treated is purely domestic, and below the average strength English sewage; the average flow *per capita* per day being about 50 gallons.

This plant was built by the City Engineer (J. B. L. Meek, M.Inst.C.E.), who has been responsible for all constructional work.

The general design of the plant is due mainly to Messrs. Activated Sludge, Limited, who also supplied the air compressors, air meters (Messrs. Kent, Limited), air mains, diffusers and inlet arrangements for the settlement tanks, etc. The effluent flow recorder was supplied by The Lea Recorder Company, Limited.

The installation is operated under the direction of the writer, but its actual working is controlled by W. T. Lockett, M.Sc., Research Chemist to the Department, and the Works Manager, H. Edwards, is responsible for control of mechanical plant.

The writer is indebted to the Rivers Committee of the Manchester Corporation for permission to publish these results.

OPERATION OF ACTIVATED SLUDGE PLANTS, HOUSTON, TEXAS.

By J. C. McVea,
City Engineer.

Houston is located in the southern part of Texas, U.S.A., about fifty miles inland from the Gulf of Mexico. In the year 1914 the United States Government, co-operating with the city, was rapidly bringing to completion a ship canal extending from Houston to the Gulf, and the city was preparing to build harbour facilities. An expenditure of $25,000,000.00 for the entire project was contemplated by 1925. To protect the harbour and canal from gross pollution, it was necessary to construct treatment plants to handle the sewage from an expected population of 225,000 in 1925. The dilution factor available was very low, necessitating a comparatively high degree of purification. As a result of experiments conducted, the conclusion was reached that the activated sludge process was the most suitable for the conditions to be met. Two plants were constructed, and operation began in 1917 and 1918. Trusting that the design and operation of these pioneer plants may be of general interest to engineers, a brief description of the plants and a tabulation of operating results for the years 1922 and 1923 are here given.

The plants are constructed in units, the north side plant having four units and the south side plant, two. Each unit consists of one aerating tank 18 feet by 280 feet with an effective depth of $9\frac{3}{4}$ feet ; one re-aerating tank 9 feet by 280 feet by $9\frac{3}{4}$ feet deep ; a battery of ten vertical flow hopper bottom settling tanks, 10 feet by 18.8 feet at the surface and 22 feet deep, equipped with 8-inch pipe air-lifts. The plants were designed on the basis of a capacity of 2.5 million gallons daily per unit, handling sewage containing 250 p.p.m. suspended solids.

The aeration is of the diffused type, the air diffusing through 12 inches by 12 inches by $1\frac{1}{2}$ inches filtros plates, so arranged that the ratio of liquid surface area to plate area is 7 : 1. The bottom of the tanks is of the saw-tooth type and the plates are set at right angles to the direction of flow. The plates were originally set in cast iron containers, but after a short period of operation they became so clogged with oxide of iron that the plate resistance increased from 0.6 to 1.2 lb. at the north side plant when passing 1.5 cubic foot of air per minute. The

oxide of iron was removed from the plates by immersing in a bath of hydrochloric acid. In March, 1920, the plates were re-set in cement concrete containers, the original resistance of 0.6 lb. having been re-established, which, however, by November had increased to 0.9 lb. At the south side plant there had been no appreciable increase in resistance for over two years. No effort has been made at either plant to screen the air other than through 8-ounce duck and canton flannel.

Air is furnished by Sturtevant No. 10 Positive Pressure Blowers, each having a capacity of 3,200 cubic feet free air per minute at a speed of 265 r.p.m. At the north side plant two blowers are driven by two 150 h.p., 2,300 volt, 3-phase, 60 cycle, electric motors, and one blower is driven by a 150 h.p. Diesel crude oil engine. At the south side plant there are two blowers, both motor driven. In each plant there is one multi-speed motor with the others having constant speed.

The plants are operated by three 8-hour shifts, consisting of one operator per shift, with such additional labourers as may be necessary, varying from one on one shift only during the day to one or more on each shift. Operators are paid from $145.00 to $170.00 per month, and labourers are paid $3.50 per day. Electric power is secured at approximately six mills per kilowatt-hour.

The cost of the north side plant, exclusive of land, was $245,000.00, and $110,000.00 for the south side plant. The north side plant site consists of 24.5 acres of land of which only about two acres are occupied by the treatment works and 1.5 acre by the sludge lagoons. The south side plant site contains fifty acres, with approximately 1.6 acre used for the treatment works and 1.5 acre for sludge lagoons.

The resultant sludge from the two plants is now being disposed of in lagoons, without offensive odours or other nuisance in the vicinity. A sludge drying plant has been installed at the north side plant, where experiments are under way for determining an economical method of preparing the sludge for market as an ingredient of commercial fertiliser.

The north side plant treats a sewage of both domestic and industrial origin, with the accumulation of nightsoil from some 10,000 dry closets. The south side plant treats a strictly domestic sewage, which is comparatively weak.

The results shown in the accompanying tabulations indicate that the activated sludge process in Houston is producing a highly purified effluent at an economical cost. The effluent is of a higher standard than really required at this time, as it contains less organic matter than the canal water into which it flows.

The costs given in the table do not include interest on the capital invested nor an allowance for depreciation.

A study of the results also indicates that certain economies in operation can be secured by a modification of the design, as for instance it is believed that the amount of air could be reduced if the ratio of surface area to plate area were less. It is also doubtful if re-aerating the sludge is of any advantage, since it has been found impracticable to carry a

OPERATION OF SEWAGE DISPOSAL PLANTS.

	North side plant.		South side plant.	
	1922.	1923.	1922.	1923.
Total air pressure in pounds	5.36	5.38	4.95	4.99
Total free air a day in million cubic feet	11.7	12.3	2.85	2.90
Ratio of air, in cubic feet, to U.S. gallon sewage	2.24	2.25	1.98	1.61
Total air to each filtros plate in cubic feet a minute	2.5	2.2	1.83	1.88
Sewage treated, in million U.S. gallons a day	5.1	5.22	1.41	1.76
Sludge in aerating channels, per cent., 30 minute sedimentation	20.6	20.8	16.9	13.2
Sludge in re-aerating channels, per cent., 30 minute sedimentation	29.5	27.7	26.5	18.8
Ratio of re-aeration liquid to sewage	2.32	3.02	1.76	2.35
Mean aerating time, hours	4.17	5.03	5.54	4.40
Ratio of sewage in gallons a day to settling tank area in square feet	905	775	750	935
Salaries of operators and labourers	$11,848.25	$14,004.23	$7,384.65	$6,450.00
Other expense	3,042.49	4,863. 7	742.79	605.27
Fuel and power	10,756.77	12,450.51	2,385.64	2,633,97
Total operating expense	25,647.51	31,318.31	10,513.08	9,689.24
Cost million U.S. gallons	14.02	16.30	19.08	15.15

LABORATORY.

(RESULTS IN PARTS PER MILLION).

	North side plant.				South side plant.			
	1922.		1923.		1922.		1923.	
	Sewage.	Effluent.	Sewage.	Effluent.	Sewage.	Effluent.	Sewage.	Effluent.
Nitrogen as free ammonia	22.5	8.9	19.2	7.2	16.9	4.3	16.5	5.0
Nitrogen as nitrites	0	1.7	0	2.0	Tr.	2.7	0	3.4
Nitrogen as nitrates..	0	2.9	0	4.1	0	9.9	0	11.3
Suspended solids	348	29.2	272	34.3	166	7.5	145	9.1
1-day biochemical oxygen demand	55	4.4	36	3.6				
5-day biochemical oxygen demand	161	11.3	120	8.2				
Dissolved oxygen	0	4.3	0	3.9				
Reduction in suspended solids, per cent.	91.4		87		95.5		93.7	
Reduction in 5-day O. demand, per cent.	93.0		93.1					
Relative stability	90.0		90.0		98		98	
5-day O. demand in canal above plant	30							
5-day O. demand in canal below plant	18							

concentrated sludge, as intended, through this channel. With a concentrated sludge the air is not finely diffused, but tends to accumulate in large bubbles. Using a thin sludge makes it necessary to return a larger volume of liquid, causing a shorter minimum detention period in the aeration tank.

Hopper-bottom settling tanks are more or less difficult to operate, the sludge clinging to the sides until putrefaction sets in, with a tendency to rise to the surface. It is believed that by eliminating the reaeration and installing mechanical clarifiers in the settling tanks, the capacity of these plants can be increased at least twenty per cent. When additional capacity is needed, it is proposed to make this change instead of constructing an additional unit.

Mr. T. Chalkley Hatton (Milwaukee, U.S.A.), who presented Mr. McVea's paper, in the absence of the author, described the method adopted by Mr. McVea for preparing the sludge for sale as a fertiliser. His process consisted of first injecting SO_2 in certain definite proportions, and then passing the sludge through a cloth filter, such as was used in paper manufacture. It was thus reduced from a moisture content of 98 per cent. to one of 80 per cent. The resultant sludge was passed through a direct-indirect drier, in which it was subjected to a temperature of about 750 degrees F. for a period of 40 to 45 minutes, and from whence it was ejected in the form of sludge containing about 10 or 12 per cent. moisture. After that it was partially pulverised, bagged and shipped. It contained approximately 6 per cent. of ammonium nitrate, 65 per cent. of which was available for plant food. The rest became a humus. Mr. McVea had marketed the product a distance of 1,000 miles from the plant.

SEWAGE DISPOSAL PLANT FOR THE CITY OF MILWAUKEE, U.S.A.

By T. Chalkley Hatton,

Chief Engineer, Sewerage Commission of the City of Milwaukee.

The industrial city of Milwaukee, with a present population of approximately 500,000, is located on the western shore of Lake Michigan, a fresh water lake about 118 miles wide and 300 miles long, at the confluence of three rivers, about the banks of which the city is built.

The sewage is collected by a "combined" system of sewers, approximating 600 miles in length, which discharge their contents, without treatment, into the three rivers. These rivers are all navigable for vessels of 10,000 tons burthen for from two to three miles above their mouths. The current through them is extremely sluggish, and they have therefore become great elongated septic tanks, which, in the summer season, generate and disperse odours which are very unpleasant to the occupants of the large number of office and merchant buildings and industrial establishments along their banks and to the major portion of the city's population which daily passes over them.

The lake water, being naturally pure and cold, is the logical public water supply. The supply is taken from a submerged inlet, 75 feet below the surface, 6,500 feet from shore and about five miles distant from the joint mouth of the three rivers. With these rivers discharging daily about sixty-five millions of gallons of raw sewage into the lake at a point five miles from where an equal volume of water is taken for the public water supply, and, with nothing but the wind to influence the direction of flow, only one result might be expected, a sewage-polluted water supply. While the danger from this pollution could be largely reduced by filtering and chlorinating the water supply, there are meteorological conditions of frequent occurrence which so influence the currents in the lake that these agents cannot alone be depended upon for a continuous pure supply unless the sewage is treated by some process which will at all times ensure an effluent of unusually high standard. This was the primary object in the mind of the designer of Milwaukee's sewage disposal plant during the five years of scientific investigation and demon-

stration prior to determining the type of plant most suitable for the conditions.

The secondary object was to adopt a process which would produce a sludge which might be disposed of without nuisance to the citizens of Milwaukee, or to their suburban neighbours, both semi-urban and agricultural.

The chief sanitary and engineering officers of the Federal Government having control of the navigable waters strongly advised against disposing of the sludge by barging it out and dumping it into the lake, as they felt the time was rapidly approaching when this method of disposal would be inimical to public policy.

There is no waste land in the immediate proximity of the City of Milwaukee upon which any considerable volume of sludge could be deposited without creating a nuisance which might soon be stopped by either legislature or court action. The character of the land for agricultural purposes, and the climate for the major part of the year are not favourable for disposing of wet sludge upon land, as is so widely done throughout the British Islands, and to which the average American strongly objects, particularly if he happens to reside nearby.

The solution of the primary object was child's play in comparison to that of the secondary object, and two or more processes of treatment could have been satisfactorily adopted, such as sedimentation followed by trickling filters, or chemical precipitation. Both of these, however, and in fact all other processes investigated, produced a sludge which was so low in fertilising value as to preclude a practical market.

The activated sludge process, from the beginning of our investigations, gave promise of producing a satisfactory effluent at all times, was susceptible of control unknown to other processes, and of producing a sludge which, if properly conditioned, would be of sufficient value to secure at all times a market which would at least meet the cost of production. After ten years of intense investigation, the last five of which have been particularly devoted to the study of sludge, and during which hundreds of demonstrations have been made of methods and means for securing both objects, these early promises have been satisfactorily realised, except that the market for the large volume of sludge which will be produced has not yet been found. Our recent associations with manufacturers of dealers in and consumers of fertilisers have, however, convinced us of our ability to dispose of the 36,000 tons of sludge we expect to produce per year at a price which will at least pay for the cost of its production. This cost does not include that of clarifying the sewage, but only that incurred from the time the sludge is removed from the sedimentation tanks until it is delivered to the manufacturer of or dealer in fertilisers.

From recent publications of British engineers coming to the notice of the author there seems to be a prevalent notion in England that the production of a marketable fertiliser from the sludge produced by the activated sludge process has not been satisfactorily accomplished.

The author believes this to be an error, probably because the facts have not been properly presented to our English colleagues.

The Sewerage Commission of Milwaukee created a Fellowshi in the Agricultural College of the University of the State of Wisconsin for the purpose of studying the theoretical and growing value of the activated sludge not only as a complete fertiliser but in combination with other well known mixtures and upon different types of soils with different kinds of plants.

After securing sufficient data to warrant it in concluding that the sludge was a profitable fertiliser if used properly it created a department under its chief engineer to co-operate with its Fellow in bringing to the attention of other agricultural colleges, manufacturers, dealers and consumers, throughout the area in which the sludge could be profitably shipped, the value of the sludge as a fertiliser either by itself or in combination with other ingredients.

The Sewerage Commission became a member of the National Fertiliser Association, and a subscriber to its Soil Improvement Committee, thus standing upon the same plane as any other manufacturer or dealer in fertiliser and becoming a co-partner therewith. The result so far has been to convey to the minds of those who will be our future customers that we have a product which they want, and to be able to fix a price therefor. This work will be continued vigorously until we find a ready market for all the sludge we produce.

From the author's somewhat limited knowledge of the methods so far pursued in England in developing the activated sludge process, he has the opinion that the aim has been to produce a clarified and stable effluent with the least expenditure of air and without much attention being given to the character of the sludge produced. From the author's viewpoint both sides of the problem must be solved together, that is the character of the sludge produced is of equal importance to the engineer as is the character of effluent produced, and if by using more air or longer contact a sludge can be produced which is higher in available nitrogen or which can be dewatered at less expense, then the additional air and greater period of contact should be used. It follows naturally that these additions also produce a higher quality of effluent.

In dewatering the sludge the same is true ; that is if acid or alum mixed with the sludge before pressing or filtering produces more sludge per unit of time, containing less moisture and more nitrogen or greater availability, that which gives the best combination should be used.

After the bulk of the water is removed by pressing or filtering, the drying is a simple process which may probably be done with any type of dryer which will not scorch or burn the product, and for this purpose an indirect or direct-indirect dryer should be used. The filtered or pressed sludge is a sticky, greasy substance, and will ball up soon after the heat in the dryer strikes it ; to overcome this tendency we have found it necessary to add to this sludge, before it goes into the dryer, about

an equal quantity of the dried material, which reduces the moisture per volume in the sludge and prevents it forming large balls of semi-dried material. The plans upon which the sludge dewatering plant for the City of Milwaukee is being built may be briefly described as follows:

The buildings are being constructed to take care of two million gallons of sludge per day, containing 2 per cent. of solids. The equipment being installed will take care of one and one-third million gallons per day, the estimated quantity produced from the treatment of eighty-five million gallons of sewage. The dried sludge (10 per cent. moisture) is estimated to be one hundred tons per day weighing 50 lb. per cubic foot.

The temperature of the sludge varies from 40° F., during the winter months, to 75° F. during the summer months.

After settling in sedimentation tanks, which are equipped with Dorr clarifiers, the sludge is removed by hydrostatic pressure due to the difference between the elevation of the surface of the water in the tanks and the surface of the sludge in the sludge conduits which carry it by gravity to sludge pumps. These return it to the fine-screened sewage, with which it is returned to the aeration tanks, the surplus passing to the acidification tank before it reaches the fine-screened sewage conduit.

After reaching the acidification tank, sulphuric acid in the proper quantity to reduce its pH value from 7 or 7.5 to from 3.2 to 3.6 is added to the sludge and is thoroughly mixed with it by aeration, the mixing continuing for a period of from 15 to 30 minutes.

From the acidification tank the sludge is pumped through the copper tubes of heat exchangers, thence through a condenser which is a part of a steam turbine electric generator of 1,250 k.v.a. capacity, and thence to twenty-four vacuum continuous filters of the Oliver type, each of which is 11 feet 6 inches in diameter by 14 feet long, revolving on a horizontal shaft at a controlled speed of from four minutes to fifteen minutes per revolution according to the condition of the sludge.

From the surface of these filters the sludge is blown off by air in thin sheets from one-sixteenth to one-quarter of an inch in thickness and containing from 75 per cent. to 80 per cent. moisture.

It is then conveyed by belt and screw conveyors to the dryers. On its way a pre-determined percentage of the dried sludge is automatically added, the two becoming thoroughly mixed by means of the screw conveyors before reaching the dryers.

After passing through direct-indirect dryers, each of which is 60 feet long and 84 inches in diameter, and retains the material for 45 minutes, the dried material is conveyed to rotary screens, the finer particles being conveyed to the storage house by belt conveyors, the coarser passing through a pulverator and thence being conveyed back to and discharged into the wet cake conveyor.

It has been found that during the three cold months of the year the sludge produced at the Milwaukee plant cannot be economically dewatered by any apparatus thus far tried out, unless it is heated to 120° F. or more. For this purpose the exhaust steam from the steam turbine

is used, as is also the heat in the filtrate from the vacuum filters, which, after passing through the condenser and receiver, passes through the heat exchangers on the outside of the exchanger tubes ; thus transmitting the heat units in the filtrate to the cold sludge inside the tubes.

The turbo-generator supplies current for operating the numerous motors throughout the plant, and is run condensing during seven months in the year, and is so controlled that during the other five it can be run from no vacuum to 28 inches, according to the amount of exhaust steam required to bring the sludge passing through the condenser to the temperature required.

Owing to the seasonal market for the activated sludge it has been found necessary to build a storage house with a capacity for holding 16,000 tons of sludge. The sludge will be handled by means of an electric travelling crane, operating a grab bucket. From the storage bins the sludge can be run by gravity into cars and shipped by bulk, or in bags.

The screenings produced by the fine screens cannot be successfully handled with the sludge. It is estimated that there will be approximately 36 tons of these screenings per day, containing 85 per cent. of moisture. These could be pressed and dried, but their value after such a process would be practically nil as a fertiliser, whereas if they are digested first, and then dried, their value is about one-third greater than the sludge. We therefore believe it will be profitable to thus dispose of them, and for that purpose we will put them through a horizontal digester 40 feet long and 84 inches in diameter, in which they are first subject to a stream pressure of 125 pounds for one-half to three-quarters of an hour, then to a vacuum for from five to six hours, which digests and dries them to 10 per cent. moisture. When thus treated they contain about 7½ per cent. of nitrogen as ammonia, 75 per cent. of which is quickly available as plant food.

The estimated cost of the sewage disposal plant, most of which is now under contract or built, is eight millions of dollars.

The estimated cost of treating the sewage is twenty-two dollars per million gallons, and that of treating the sludge and screenings thirteen dollars per million gallons of sewage. About one and one-quarter tons of dried sludge is produced per million gallons of sewage treated. The above costs include all overheads, such as interest and depreciation.

At present market prices (which are unusually low) for organic nitrogen as fertiliser, the sludge, which contains 7½ per cent. of such nitrogen, is worth 15.00 dollars per ton, or 2.00 dollars per unit, and the screenings 18.75 dollars or 2.50 dollars per unit.

A very good description of the Milwaukee plant has been published in the "Proceedings of the American Society of Civil Engineers," vol. lxxxv., 1922, by Darwin W. Townsend.

DISCUSSION.

Mr. Chalkley Hatton, in presenting his paper, put forward a plea for the disposal of sludge in a sanitary manner, and urged that markets should be found for it as a fertiliser. He assured those present, especially

British sanitary engineers, that he was not making his remarks in the form of criticism. In fact, he felt that whatever information he had obtained in connection with the art of sewage disposal the English engineers were responsible for. They had been his mentors and he thanked them for it. He had been experimenting with the activated sludge process for the last eight years, assisted by most competent investigators. Fortunately, he had a Board which was composed of five men who were broad-minded enough to allow him all the money he needed to spend to get the best assistance he could possibly obtain. So far, however, in the activated sludge process, it seemed to him that the burden of the work had been done with a view to diminishing the cost of clarification of the sewage. He agreed that to design plant with a view to cutting down the cost of air was a very creditable thing to do, and he had no doubt that they could get, not complete purification, but a standard high enough to accommodate almost any conditions by the use of one cubic foot of air per gallon of sewage treated, or even less, even with strong industrial sewage. But that was not the whole story. In fact, he believed it was the smallest part of the story—and he spoke from experience. The problem was to take care of the sludge which was produced after using the air. Until it was recognised that that was the real problem, he ventured to say that the activated sludge process would never become popular in any country in the world. They had to get rid of the final sludge, and they must get rid of it in a sanitary manner. He submitted that few, if any, of them were disposing of it in a sanitary manner. It was said that it was not attractive to the fertiliser user. Certainly it had not been attractive ; they had not put it into an attractive form. But when they did put it into an attractive form, so that the farmer could use it as he used all other fertilisers, he ventured to predict that they would have no trouble whatever in convincing the average farmer, or rose grower, golf-course keeper or trucker that he ought to use that sludge. He expected it was the case in England, as in America, that the fertiliser manufacturer was gradually losing the organic nitrogen he needed to make his best fertilisers. For instance, before the war, in the large packing plants in America, they were producing organic nitrogen from the tankage, but they are not doing so now. They had found during the war a much more valuable market for the tankage by converting it into a cattle food, so that the organic nitrogen they were then producing was out of the market. The fertiliser manufacturers needed organic nitrogen very much, and it was in the sludge. It was one of the best plant foods that the fertiliser manufacturers could get, and he was advised by the National Fertiliser Association, of which his Board was a member, that they could use all the organic nitrogen in the form of sludge that could be produced, and that they would pay a fair price for it. He would not hesitate a minute in advising any of his clients, where they had to treat from 1,000,000 to 2,000,000 gallons of sewage per day, to go ahead with the final process and get their sludge into a condition in which it would be available to the farmer, and he would

further advise them that that could be done at least for the price they could sell it for. That was better than disposing of the sludge in any other way, because it did cost money to put it on the land or into lagoons, or by any other method. The truck farmer would take it if it were put into proper condition ; the golf-course keeper would take it ravenously, and he ventured to say there was not a town in this country—he knew there was not in America—of 50,000 or 60,000 inhabitants, or up to 100,000, which could not dispose of its sludge, when put into proper condition, round its very doors. In Blackwell's Island, New York, they had a screening plant ; they digested the screening and put it into the form of a dried sludge. At first they did not know what to do with it, but had decided finally to bag it up into 10, 15, 20, 50 and 100 lb. bags and sell it. The public had made a raid on it, the price varying from $25 per ton up to $90 per ton, according to the sizes of the bags ; he believed a 10 lb. bag would sell at the rate of $90 per ton. It was true that they did not have very many tons in the course of a week or a month, but the superintendent of the plant had told him last January that he could dispose of 100 tons a day in the City of New York, in 10, 15 or 25 lb. bags. When anybody had a cereal to sell, or anything for human consumption, they put it into the best condition and made it attractive to the consumer ; what the engineers must do is to make the sludge an attractive article, because it was recognised that there was a great deal of plant food in it. Their job was not finished after clarifying the sewage ; they must not let the sludge take care of itself. Their job was to take care of the sludge to its final destination, and sell it so that two blades of grass would grow where one grows now.

SPIRAL CIRCULATION IN THE ACTIVATED PROCESS.

By Charles H. Hurd,
Consulting Engineer and Chief Engineer of the Sanitary District of Indianapolis, Ind., U.S.A.

The success of the activated sludge process of sewage treatment in its present stage of development is dependent almost entirely upon the economic use of power for aeration and circulation and the advantageous disposal of residual sludge. From its inception, the character of the effluent produced by this method has given but little anxiety, but the operating costs—particularly the expense of supplying power—and satisfactory means of the disposal of solid wastes have been of almost universal concern.

On account of the sanitary advantages of this system, including the very superior effluent and operation without the production of objectionable odours or local nuisance, much effort has been directed toward the solution of these problems. Studies and investigations have been made, involving the biological, chemical and mechanical characteristics of the process, and while there may be general agreement as to the procedure and results, it is also agreed that the fundamental and inter-operating conditions and principles are only imperfectly understood.

Admittedly, the activated system is a bio-chemical process. As conventionally operated, it consists in supplying oxygen to the sewage in the presence of inoculating media under conditions to produce rapid nitrification of the organic matter, followed by a separation of the contained solids. It is conceded by most investigators that the quantity of air required for oxidation under favourable conditions is small. To produce the best conditions, active biological media must be brought into immediate contact with the organic matter in the sewage in a manner to promote rapid and progressive bio-chemical development. The circulation of the sewage volume, in other words, during the period of activation and aeration, is most essential. The experimental investigation of the Indianapolis laboratory was directed toward this feature of the work, where progress was made in improving the effectiveness of spiral circulation, which is the subject of this review.

INDIANAPOLIS DEMONSTRATION LABORATORY.

At the beginning of the experimentation, it was realised that economies must be effected in the use of power for circulation in the aeration period

in order that this process might be applicable to conditions at Indianapolis. To this end, separate tanks were equipped for mechanical agitation, for ridge and furrow diffusers and for spiral circulation. At the end of the first year, the mechanical and the ridge and furrow types were abandoned and all further efforts were confined to the spiral unit.

SPIRAL CIRCULATING TANK.

The spiral tank is constructed with a flat bottom, rectangular in plan, and is similar to the Manchester tank and the one illustrated in the paper of Arthur John Martin, Proceedings of the Institution of Civil Engineers 1923-24, except that it is not provided with rectangular compartments but has greater width and is equipped with deflecting surfaces to direct the flow and increase the circulating velocity. The spiral units were intended to be sections of the individual channels of the plant proposed for the Indianapolis sanitary district. All tanks had an effective depth of 15 feet and a sectional length of 5 feet, with varying widths of from 15 to 30 feet.

Results of these tests indicated that the upper deflector blades are most important. In fact, with deflecting surfaces placed at angles of about 45 degrees at the top of the walls and extending laterally each about 15 per cent. of the width of the tank, the velocity was increased practically 100 per cent. Contrary to the general prevailing ideas, the width of the tank—within the limits used—has but slight effect upon the velocity or operation. The bottom of the 30-foot tank was kept clean even with a use of air of 0.6 cubic feet per gallon and a rate of 16.66 m.g.d. of sewage treated per acre. The sludge returned varied from 20 to 25 per cent. during these experiments.*

OBSERVATIONS ON GLASS AERATION TANK.

Much valuable information was obtained by the use of a small aeration tank constructed with glass ends and sides. This tank was an exact miniature of the 15 feet by 15 feet demonstration unit with one-fifth the lineal dimensions. The air supplied was proportioned to that used in the larger tank with velocities comparable. The effect of deflecting baffles on the quantity of air held in suspension, as well as the surface and bottom velocities under varying conditions, was immediately apparent in this experiment. In addition to observations in the circulation of entrained air, the effect of placing finely divided solid particles into the tank was studied in order to determine the minimum velocities which would cause deposition. Measurements below one-half foot per second were more or less uncertain, but with this velocity there was no indication of deposits.

VALUE OF CIRCULATION.

Throughout the studies made on aeration at the Indianapolis laboratory, it was clearly demonstrated that repeated contact between the

* For convenience, all sewage quantities are transposed and given in British Imperial Units.

organic sewage and the active biological sludge in the presence of oxygen, and the dissolved mineral salts, has an accelerating effect on the process in addition to preventing the deposition of solids. It was concluded that positive circulation and complete intermixing not only promotes the action of the biological masses as clarifying agents but more effectively utilises the latent capacity of the returned sludge, energising new and more abundant growths through bio-chemical activity.

INDIANAPOLIS ACTIVATED SLUDGE PLANT.

The general characteristics of the Indianapolis Disposal Plant, described in the "Engineering News-Record," volume 91, 1923, page 258, are based upon the results and demonstrations at the experimental laboratory. Referring to the above article, it will be observed that this plant is built for a present nominal capacity of 42 m.g.d. and a present maximum of 60 m.g.d. with an ultimate maximum capacity of 90 m.g.d. These capacities are predicated on an operating rate of 16.66 m.g.d. per acre, although most of the demonstration runs at the experimental plant were at the rate of 20 m.g.d.

AERATION TANK CONSTRUCTION.

The aeration tanks are constructed with flat bottoms, each tank having four channels 20 feet wide and 238 feet long. The diffusers are set eccentrically in respect to the centre line of channel and in four rows. Transversely, the plates are staggered with decreasing space toward the air inlet and are interconnected by glazed vitrified pipes embedded in the concrete floor slab. The tops of the longitudinal walls are flared to form the deflecting surfaces, which also enclose the air supply lines and electric conduits.

The distinctive structural features of this plant are shown in some detail in "Engineering News-Record" in the article mentioned. Of these, the most prominent are: (1) The comparative large size of individual units, and, correspondingly, the small number of pressure walls; (2) the simple floor construction without the use of separate or precast "diffuser holders"; (3) the compact arrangement in respect to the settling tanks and the absence of mixed liquor connecting channels.

AERATION TANK OPERATION.

The purpose of the above type of design and the advantages which are expected to be realised in operation, are, briefly, the following:

(*a*) The arrangement of diffuser plates in relation to the head wall, to give positive rotation and to prevent mushrooming of the air column.

(*b*) The circulation in the air duct system through the use of the ejector and interconnections to prevent trapping of filtered sewage and water-binding of the diffusers.

(*c*) The extended width of channels, which gives more direct circulation and greater surface contact.

(*d*) The extreme combined length of channels increases the pitch of the circulating spiral and minimises the chance for short circuiting.

(*e*) The angle wall deflectors give positive direction to the circulating flow and increase the velocity of circulation and a correspondingly greater quantity of entrained air with better conditions for inoculation and oxidation.

LENGTH OF SPIRAL.

While the length of travel of the sewage in the spiral tank may not have a direct relationship to the efficiency of aeration, it is of interest compared with other types of circulation and with the natural purification which takes place in flowing streams. The surface and bottom velocity in the experimental tanks, heretofore described, approached 2 feet per second under usual operating conditions. These tanks had large wall surface compared with the volumetric contents. It is anticipated even with a lower use of air that the circulating velocity in the new units will exceed 2 feet per second. With this rate of flow and an average period of five hours, the pitch of the circulating spiral will be about 1.75 feet and the total length of surface travel will approximate seven miles.

COMPARATIVE ECONOMY.

The power plant constructed for the Indianapolis sanitary district is considered representative of its capacity and for the character of service to be rendered. The turbine air equipment is guaranteed to compress 1,000 cubic feet of free air to 7.5 lb. gauge pressure with 7.67 lb. of steam; the electric units are guaranteed to supply power at a rate of 15.3 lb. of steam per k.w.h. at the switchboard.

The latter rate above given, adjusted for transmission and transformer losses and corrected for motor efficiency, would be equivalent to about 13.65 lb. of steam per b.h.p. at the shaft of a mechanical circulating unit. Using the above figures and assuming a rate of 0.9 cubic feet of air per m.g.d. of sewage treated, the economy of air circulation would be comparable to a use of 22 b.h.p. per m.g.d. used in the mechanical tank. This, we believe, is within the limits of present day practice.

PRIMARY TREATMENT.

Except for the first few months, all experimental work on aeration, sludge settling and filtering was carried on with sewage in which the grosser suspended solids had been removed.

The method used, which is identical with the one adopted in the design of the new plant, is to pass the sewage through primary settling tanks, augmented by fine screen filters. The screens are of the revolving submerged type, placed in the influent channels and their function is to reduce the volume of the sewage before settling. The tanks which receive the concentrated sewage are rectangular in plan and mechanically

cleaned to prevent septicisation. Due to the heavy sewage, which is relatively fresh, the retention period in the settling tanks is but from 25 minutes to 45 minutes. The removal in this system is about 33 per cent. of the suspended solids.

The effect of this primary treatment on the activated process is to reduce the quantity of waste sludge by about 40 per cent. It also results in a saving in the use of air for aeration and obviates difficulties due to settling of solids in channels and conduits.

CONCLUSION.

In comparing the results of spiral circulation with other methods used at Indianapolis, it is believed that this system has many advantages over other types. Sewage treatment is always and necessarily a local question, each condition requiring individual study. Present development indicates that future progress will be through more extended biological research. We have great confidence in sanitation science and feel that these interesting though perplexing present-day problems will be solved.

DISCUSSION.

Mr. HARRISON P. EDDY (Boston, Mass., U.S.A.) mentioned a few general points of difference between the conditions in the United States and in this country. In the first place, the volume of sewage in this country was very much less *per capita*, and in the aggregate, than it was in the States. The volumes ran from perhaps 30 to 50 or more Imperial gallons *per capita* per day here, but, as a general rule, in the States the volume could be taken as 100 United States gallons *per capita* per day, or 83 Imperial gallons. But while 100 gallons *per capita* was a general average, and was approximately the volume assumed a Milwaukee, there were exceptions, and the activated sludge plant which was being built for the North Side portion of the Chicago Sanitary District had to provide for 300 gallons *per capita*. When they considered the volume of air used per gallon, it was very important to consider also the number of gallons *per capita*. Mr. Eddy also pointed out the very low cost of electric power at Houston, Texas, where it was slightly less than one-third of an English penny per kilowatt-hour. That was a very important matter to consider when studying the cost of that work. In many parts of the States a rate so low as that for so small a consumption would not be practically possible. He agreed in large measure with Mr. Chalkley Hatton with regard to the importance of providing for the sanitary and economical disposal of sewage sludge, and he believed the time was coming when in many places that would be done. Whether the sludge would be converted into a dry commercial fertiliser, or whether it would be applied directly to the land after air drying or in liquid form

depended largely upon local circumstances. At Milwaukee and other northern cities the direct application of liquid sludge to land would be exceedingly difficult, if not impracticable during the winter. Again, American conditions were such that a city was undertaking a great deal when it went into a commercial business. Political conditions in many cities were such that there was great hesitation in adopting any process which ran into a high operating cost—which seemed to be the case at the present time with activated sludge. There was another local condition which played an important part, namely, that it was much easier in many communities to secure money for capital expenditure by borrowing for a long period of years than it was to provide the annual appropriation necessary for operation. There had been cases where the authorities had preferred to make a large expenditure for construction, with a view to having the annual operating expenses comparatively low, even though a plant might be more expensive, if comparison be based upon interest, depreciation and operation cost, than some other type of plant which might involve a higher annual operating cost. Another point in connection with treating sewage by the activated sludge process was that it was not solely a question of treatment of sewage, but of treatment of the sewage in such a manner as to make practicable the dewatering of the sludge. Where it was necessary to de-water the sludge by mechanical means, there was a very important connection between the correct treatment of the sewage and the conditioning and de-watering of the sludge. Whereas a small volume of air per gallon of sewage might suffice for the treatment of the sewage, so small a proportion of air might provide a sludge which was exceedingly difficult to de-water.

Mr. H. Kessener (Director of the Government Institution for the Disposal of Sewage and Trade Waste Waters, Holland), referred to the de-watering of sludge from the activated sludge process. He had made experiments by mixing it with carbonate of lime and phosphate of lime, in order to see if it could be de-watered more quickly by that means than if it were merely put through a filter press without such an addition. By that means they could produce a fertiliser which served two purposes ; i.e., not only did it neutralise the soil (acid peaty soil), but, at the same time, it gave to the soil the nitrogen from the activated sludge, and the phosphoric acid, and it seemed to him that many improvements might be brought about by experiments in that direction in the future. He had noticed from Dr. Ardern's paper that the consumption of power had been decreased by the adoption of new type air compressors. He was glad to see that, because the price of electricity in Holland was generally high, so that the activated sludge process was not likely to be adopted extensively. He had noticed also that at Sheffield the consumption of power had been decreased very largely, and he hoped to see further improvement in that direction.

Dr. H. T. Calvert (Ministry of Health), said he had made a survey of

nearly all the activated sludge plants in this country. He felt that he was a student of the process, and would have to remain a student for a very much longer period, because the fundamentals of the process had not been sufficiently thoroughly studied. They all admired the vision of Mr. Chalkley Hatton in embarking upon the tremendous project at Milwaukee, and they were very interested to hear of the magnitude of Mr. Hurd's plant at Indianapolis. It was only by such vision that progress could be made. He fully agreed with Mr. Chalkley Hatton in what he said about the scientific basis for dealing with the sludge, and he wished to make a very strong plea for further research into the fundamentals of every aspect of the activated sludge process. With regard to the re-activation of exhausted, or partially exhausted, activated sludge, Mr. McVea had indicated in his paper that it was not profitable to re-activate a concentrated sludge. In one of the other papers, however, he rather gathered that re-activation was advocated. That was one of the problems on which further information was required. A very successful attempt had been made to utilise a modification of the activated sludge process at Birmingham, where difficulties had been encountered in the re-activation of the concentrated sludge, and he felt sure that a further investigation would enable them to draw a balance as to the concentration of the sludge which it was most profitable to re-activate.

Professor S. Rachkovich then addressed the conference in French.

Mr. F. W. Harris (City Analyst, Glasgow) said it had been both a pleasure and an education to listen to the papers read that morning, more particularly as many of them were descriptive of the construction, operation, and efficiency of large installations in America.

Dr. Calvert had referred to the fundamentals of the activated sludge process, and urged the necessity for their investigation. He (Mr. Harris) might remark that for some time past an investigation on these lines had been in progress at Glasgow, the immediate practical object in view being to determine the possibilities of accelerating the process. His experience had been that the amount of purification obtainable by the activated sludge process attained a maximum within a definite period of time, the duration of which varied with the character of the sewage treated and the modification of the process employed. Prolongation of the aeration or agitation period beyond this limit led neither to increase in the efficiency of the process nor to improvement in the quality of the effluent.

He had determined that under certain conditions it was possible, within the short period of one hour, to obtain from 60 to 65 per cent. of the maximum possible purification. The primary essential condition to maintain continuously this velocity of purification, or more correctly, this intensity of biological action, was re-aeration of the sludge.

In view of this experimentally determined fact, he was rather surprised at the opinion expressed in the paper by Mr. McVea that it was doubtful

if the re-aeration of the sludge was of any advantage, an opinion which was in agreement with the view expressed by Mr. Eddy during his recent visit to Glasgow.

It was quite possible that, if the tank capacity provided were sufficiently large to permit of comparative long periods of aeration, the re-aeration of the sludge might prove of no material advantage in respect to the quality of the effluent. On the other hand he had convincingly demonstrated that the re-aeration of the returned sludge accelerates the process by shortening the aeration period, thus proportionately increasing the capacity of a given unit.

Therefore, in respect to the volume of sewage treated, re-aeration of sludge possessed a distinct advantage.

Mr. G. W. Fuller (New York) stressed the need for recognising the individuality of the problem of sewage treatment in the various localities, and on either side of the Atlantic. For instance, Mr. McVea's paper dealt with an interesting experience in the far south, near the Gulf of Mexico. He (Mr. Fuller) had not gathered what the temperature of the sewage was, but temperature must be a factor, because they took water from wells 500 to 600 feet deep. Then they had the advantage of an unusual arrangement between the city and the authority supplying electric current. Investigations which he had made had shown that the activated sludge process did not work out nearly so economically as other processes, so that Mr. McVea's statement that the process was the most economical must not be taken as being applicable generally. He was a firm believer in the need for studying locally the individuality of the different problems. With regard to the paper by Mr. F. A. Dallyn (of Toronto), dealing with Canadian sewage disposal plants—which is printed on pp. 284—292—Mr. Dallyn was dealing, not with broad experience, but from his experience in the province of Ontario, and was satisfied that, for the smaller plants, the activated sludge process had a real future there. His method of dealing with the sludge was to septicise it in the old single-storey tanks found alongside quite a number of their activated sludge plants. He (Mr. Fuller) believed there were instances where sludge disposal must be handed along lines such as those which Mr. Chalkley Hatton had put before them so forcibly. He believed there were other cases where it could be demonstrated clearly that the cost of preparing the sludge in a form suitable for putting on the market was in excess of the return that could be obtained from the sales. That was another reason why the local conditions must be studied in each case.

Mr. F. C. Temple (Jamshedpur, India) pleaded for the standardisation of the terms used in connection with sanitary engineering. This was of enormous importance to people such as himself, who had to work in the far parts of the earth. For ten years he had worked in India, where there were probably—without any sort of boasting—not more than ten people

who knew as much about the subject as he did. That was not because he knew much, but because there were so few who knew anything. In a country such as that there was little or no opportunity of meeting people and talking over ideas with them, and therefore, it was necesary to depend upon books and professional papers. Sometimes, when starting on a new problem, he had collected every paper that he could hear of on the subject, but—especially in connection with sewage disposal, though other subjects were much the same—before getting through them he had gone nearly mad with rage because no two people talked in the same terms. In a collection of 71 descriptions of sewage works, there were only 38 that gave the strength of the sewage in any form whatever, and, as the crude sewage was the raw material, on which the works were based, that method of writing could only be described as stupid. That made it extremely difficult for a person who could not talk things over with other people to find out what they meant. For some years, therefore, on every possible occasion, he had preached the desirabliity of establishing some terms which would hold good throughout all sewage disposal work. Referring to his experiences in connection with sewage disposal works in India, Mr. Temple pointed out the caste difficulties which arose when employing native labour. For instance, the use of the Dorr clarifier was almost out of the question in that country, because no skilled workman except of the lowest caste would touch anything that had been in the sewage. For this work they had to employ the lowest class of workmen, the least educated, and the most difficult to deal with, so that everything had to be as simple as possible. He himself had succeeded in making hopper settling tanks, in which the sewage did not stick on the slopes. All that was necessary was to provide sufficiently steep slopes, and also to be able to remove all the sludge which collected at the bottom of the hopper, at any moment. For that reason there was a great deal to be said for having individual lifts at the bottom of each hopper. It was quite easily done with air lifts, and, so far as his own experience went, it was a retrograde movement to go from that—as had been done in some installations—to the process of removing the sludge from the bottom of the hoppers by ordinary hydrostatic head produced by the flow of the sewage. An air lift at the bottom of each could flush out any one quite suddenly if it gave trouble. Again, he did not think sufficient attention had been paid to the effect produced by the rate of circulation of the sewage through the activated sludge tanks—in particular through the aeration tanks. There were two factors governing the movement of the sewage. There was the movement directly due to the volume of the sewage entering the tank, and an additional velocity by reason of the return flow from the hoppers. He had been experimenting a good deal on that, and had found that very remarkable results could be produced by increasing the return flow according to the strength of the sewage. Of course, he was talking of a comparatively small plant. The plant, as designed, was intended to deal with 150,000 gallons of sewage per day, for 3,000 people. The whole outfit had cost about £10,000, but, after experimenting

here and there—the additions and alterations only cost another £20—the plant had been made to deal with the sewage of 6,000 or sometimes even 8,000 people, and with a flow of 240,000 gallons on occasions; and the main factors in dealing with a greater quantity of sewage had been the return of the sludge from the settling hoppers, the rate of flow through the tanks, and the greater aeration produced by turning the sewage over more quickly. As to the disposal of sludge. In such a country as India the disposal of sludge was, as a rule, easy, because there was unlimited land which was very much in need of fertilisers; in most towns it would probably be possible to deal with the sludge without settling it at all, but by letting it flow on to the land through the irrigation channels as required, with the effluent which would be used for irrigation. The effect on the crops was illustrated by figures obtained on some test plots of land. Out of 20 plots, 10 were irrigated with clean water from the town water mains, and 10 with the effluent from the activated sludge plant. Each plot was 1/40 of an acre in extent. The plots were manured with various manures, and the amount of nitrogen put on each was measured. The plot irrigated with clean water and not manured produced green fodder crop at the rate of 700 lb. per acre. Another irrigated with activated sludge effluent and treated with the amount of farmyard manure recommended by the Poona Agricultural College, produced 15,000 lb. per acre; and a similar plot, treated with the same quantity of nitrogen as in the former case, in activated sludge, produced 30,000 lb. per acre.

Mr. J. H. Garner (Chief Chemist, West Riding of Yorkshire Rivers Board) was pleased to find Mr. Chalkley Hatton proposing to tackle the question of disposing of the sludge in what he considered to be a straightforward and sensible manner. After some years' experience he had found that in the case of large towns and cities, if one was to dispose of the sludge regularly and satisfactorily, it must be put into the form of something like a powder, with not more than about 10 per cent. of moisture. If that were done there would be a continuous demand, and the buyers would always be willing to pay what he considered to be a fair market price for the material. In this country, especially in large towns and cities, greater attention should be paid to the preparation of the sludge in a portable form, and if that were done he anticipated no difficulty in disposing of it. Unfortunately, some capital was required in the initial stages, and corporations were about the last people to provide any capital to carry a scheme of this description over the first two or three years of its life. Hence, in the past, the majority of the schemes that had been started had been given up because the corporations concerned were not willing to finance them over the critical period. Mr. Garner urged, with Dr. Calvert, the investigation of the fundamental principles of the activated sludge process, especially because we had reached a stage when, instead of giving proper scientific consideration to the matter before making an advance, we were beginning to suffer from the same ills as earlier processes had suffered from. We were having quite a lot

of spasmodic experiments without much object in view, and some of those experiments were not even persevered with. Therefore, it was advisable that some kind of research station should be established, in which attention could be directed to the fundamental principles of the process, so that work need not be repeated in numerous experimental stations. Some direction was required from the head, to direct the energies of councils and local authorities into particular grooves. Mr. Garner agreed with Mr. Temple as to the necessity for the standardisation of expression of results of analysis. The United States Public Health Service had already tackled the matter in the correct way, and had published their standard methods of analysis. We, in this country, were likely to follow in their steps in the near future. The Association of Managers of Sewage Disposal Works had prepared, in draft, standard methods of analysis, upon which it was expected that a conference of representative bodies would be held in a very short time.

Mr. G. Peel Harvey (Copenhagen) said there were as yet only two small activated sludge installations working in Scandinavia. One of these was treating exclusively the water closet discharges from 1,500 employees at a shipbuilding yard at Copenhagen, and was built entirely underground under the dockyard quay. This sewage was of course very concentrated, the flow being only five to six gallons per head per day. This replied to the point raised as to the use of the activated sludge process for treating concentrated domestic sewage, because the results were quite satisfactory.

Some years ago the speaker had compiled an approximate "air efficiency table" from the published results from activated sludge plants in various parts of the world. Roughly speaking the strength of the sewage divided by the cubic feet of free air per gallon required for treatment gave a comparative efficiency figure. For example, a sewage of strength 48 requiring 0.8 cubic feet of air per gallon gave an efficiency figure of 60; a sewage strength 80, air consumption 1 cubic foot per gallon gave a figure of 80; and sewage strength 180, air consumption 1.8 cubic foot per gallon gave a figure of 100. The figures are of course, affected by depth of activating tanks, percentage purification obtained, etc., but the table indicated clearly that the air consumption did not increase proportionately with the strength of the sewage treated.

As regards working costs for small activated sludge plants; at the installation at Holbe, in Denmark, for 5,000 persons they used 88 units per day at about 1.2 penny per unit. This was equivalent to one fiftieth of a penny per day per head, a not unreasonable figure for such a small plant, bearing in mind the fact that the site of the disposal works was such that one dared run no risk of smell from the works, so that the choice of method of treatment was practically confined to the activated sludge process.

The speaker would like to ask Mr. Hurd how he treats the 30–40 per cent. of the suspended matter removed at Indianapolis prior to the

activated sludge treatment. If this could be left in it would increase and enrich the surplus activated sludge recovered, which would appear desirable in the light of Mr. Chalkey Hatton's evidence of the income to be obtained from the sale of the sludge. Possibly Mr. Hurd had proved that the saving in expense effected in handling separately the suspended matter extracted prior to activated treatment more than compensated the loss in manurial value; otherwise, without personal knowledge of local conditions, one would be inclined to favour treating the whole of the sludge in one process.

Mr. Hatton had shown that under the conditions prevailing at Milwaukee it was profitable to recover as much sludge as possible, bring it to the condition of an artificial fertiliser and sell it. No doubt many English engineers would be indebted to Mr. Hatton if he would show them *how* to sell it. This was not, of course, Mr. Hatton's job, but there was no doubt they would be very grateful.

Mr. Harry Taylor (Newcastle), referring to the Withington Sewage Works, asked Dr. Ardern what was the approximate dry-weather flow. Also, did they wash the air or filter it before it was compressed? If not, did they find a great increase in the horse-power required? Again was the sewage strong, medium or weak? As to the Houston plant, Mr. McVea had stated that the sludge was passed through a large lagoon, about one-and-a-half acres in extent, and he (Mr. Taylor) would like to know how long the sewage took to pass through it. What was the method adopted at Houston for drying and bagging the sludge to render it suitable for sale? With regard to the Indianapolis plant, Mr. Hurd had said that he separated from 30 to 40 per cent. of the solids before aeration. Would he say what he did with the sludge which he separated in that form? Mr. Taylor then referred to the fact that in America what he might term the dry-weather flow of sewage ran from 90 to 100 Imperial gallons per head per day, whereas in England it was usually from 30 to 35 gallons—a ratio of three to one. He expected the excreta and other matters would be practically the same in the two countries, and he asked whether there was any material difference in the quantity of air used *per capita* for the treatment of the sewage.

Dr. Jan Smit (Amsterdam) said that little had been said about applying liquid sludge to land, and he would be very glad if the discussion threw some light on the question of whether it was necessary first to dry or powder the sludge or whether it should be applied as such to land. He had heard that much of the fertilising value was saved when the sludge was not dried.

Madame Wibaut (Amsterdam) said that the sewage of Amsterdam was put into the sea, and some into the public canals; but the city had suburbs which could not dispose of their sewage in this manner because of the low level of the polders on which they were built. The activated sludge process would be very suitable for these suburbs, but information was wanted on the subject. The sewage was domestic sewage; there

were no factories. It was very strong ; in England there was produced twenty to thirty gallons a head, but in these suburbs of Amsterdam, which were chiefly inhabited by labourers and their families, there was only about five gallons per head. She was informed that it was possible to make activated sludge from this strong sewage but that it would be necessary to increase the quantity of air, and she would like to know what would be the cost of doing this ? How would fat be dealt with ? A second point was that these suburbs were built in the meadows. Could the activated sludge be used in those meadows without risk of contaminating the milk of the cows that grazed there, possibly spreading typhoid fever ? A third question was, supposing there were no farms to take the activated sludge, dried or moist, would it be more practical to let the commercial aspect drop, make a septic tank and let the sludge work out so that nothing remained ?

Mr. F. T. Hambleton (Macclesfield) said they had heard that morning about activated sludge dealing with sewage from which solids had been eliminated. He thought it would be of interest to some of the delegates to hear what it was intended to do at Macclesfield. There they were putting down an activated sludge plant on a certain system which was intended to deal with tank effluent, for this reason, that they had a very difficult, dense trade sewage, and they thought that if they dealt with the tank effluent they would eliminate the danger of upsetting the activated sludge by flushes of this trade waste. When this waste had gone through the tank, it was mixed with and diluted by the weaker sewage which had gone before it, and therefore, he thought, they could more easily deal with it. They intended to use it, not absolutely apart from the percolating process, but for what they called a buffer plant. During certain hours of the day they had this trade waste coming down as quite a large proportion of the flow, and at that time the activated sludge plant would be brought into operation. But during the night they proposed not to deal with the weaker sewage coming down by the activated sludge process, but to re-aerate the sludge in preparation for the next day. One gentleman had asked about the results of applying sludge to land. He (Mr. Hambleton) had only had experience of applying sludge in a liquid form, but he had had nothing but success from that way of disposing of it. In 1919 from ten acres of land he had been able to hand over to his Council practically £1,000. Last year, when prices had dropped a great deal, he handed over £400. The crops chiefly grown were mangel wurzels, swedes, cabbages and rye grass. At Macclesfield they had now taken over a large area of land, and already he had got promise of a fair crop by applying sludge. The difference in the colour of the oats could be seen. He had two pieces of land, and on one he had put sludge, and on the other not, and the difference in the size and quality of the crops was marked.

Mr. Robert Eaton (Blackburn) said that his borough was putting wet sludge on farm land. They had an area of 570 acres, formerly acquired for sewage disposal by broad irrigation. They had, however,

adopted a biological scheme including septic tanks, percolating filter beds, and humus tanks, and the existing irrigation main, twenty-one inches diameter, and the six inch diameter distribution pipes were now used to convey wet sludge from the various tanks to the old irrigation areas where it was broad-spread by men with squeegees.

If they were putting down a new main one of twelve inches diameter would be chosen instead of twenty-one inches, as in the larger main the flow is so sluggish in a gravitational scheme ; moreover the larger main acts as a long settling tank.

The amount of wet sludge (98 per cent. moisture) recovered daily from the tanks was approximately 100 tons and the whole yearly production was disposed of on 300 acres. The cost of sludge distribution over the land was simply the wages of four men per annum. This was for a population of 130,000.

The corporation sewage estate comprised twelve holdings let to tenant farmers who paid the prevailing local rents. Good crops—chiefly grass and cereals--were obtained and the process of sludge irrigation gave very little effluent.

Dr. Ardern said in reply to Mr. Kessener that he was quite satisfied with the efficiency of the two new compressors constructed by Messrs. Jones and Attwood of Stourbridge, but he was hoping that with a larger scale plant for the new extensions this efficiency would be improved upon. These efficiencies had been taken at the low working pressure of 4 lb. At 7 lb. he believed the efficiency would work out at about 58 per cent. In reply to Mr. Taylor—the dry-weather effective capacity of the plant was 1,000,000 gallons a day, which was what it was designed to treat. His experience of the application of the activated sludge process was that provided you could look after the dry-weather flow, the question of the treatment of storm water was a simple one. The air used in this plant was not washed or filtered. He (Dr. Ardern) would not say there was not any trouble in that connection, but for years the porosity of the tiles did not increase more than 1½ lb. At the present moment they were renewing the diffusers in the first plant, which had been in operation for about seven years. With regard to the questions by Madame Wibaut, some of these were very difficult. He had already indicated that in his opinion—this was mainly a question of opinion—about a certain strength, the more difficult it was to treat your sewage and keep your sludge in a thoroughly active state, and he would not say that a 5-gallon *per capita* sewage could be treated very simply by the activated sludge process. He believed it had been done in India, but it was not an easy proposition in his view. On the other hand, it should be remembered that in connection with the cost of treating an average strength of English sewage, say thirty gallons per head, relatively six times the air supply could be employed, so that you had a very fair margin. As to the effect of fats, this was a difficult matter. It depended in the first place, whether they were purely edible fats from kitchen and scullery, or whether it was a question of industrial oils or wool-scouring waste liquor from

manufactures. The latter was a separate problem. He did not think one would attempt to apply the activated sludge process direct to sewage where the prime contributing waste was wool-scouring waste containing, of course, a very large proportion of soaps, etc. With regard to the disposal of the sludge where there was no market for the fertiliser, Mr. McVea's paper showed that for years it was possible to look after or care for the surplus activated sludge by deep secondary fermentation lagoons; but in that respect it must be remembered that there was a considerable difference between the average conditions in Amsterdam and at Houston. It might be worth their while to consider the use of adventitious heat. Another possibility, where there was likely to be extreme difficulty in dealing with the actual sludge as a fertiliser, was to recover the nitrogen in the sludge by closed distillation. Generally speaking he was not in favour of this method of treatment of nitrogen because it involved losses and considerable cost, but in certain conditions it was not out of the question.

With regard to Mr. McVea's paper, it was a source of great gratification to those early engaged in developing the process in this country when they heard that so large a plant had been put down at Houston. At the time, it was of great value in arousing interest in the process and had been a lever which sanitary engineers in England had been able to use with advantage in their own particular localities. He (Dr. Ardern) had had the pleasure of seeing that plant, and, if there was any necessity to do so, could corroborate Mr. Hatton with regard to the lack of nuisance from the septic fermentation of the sludge. He had been very much interested to hear about the trouble Mr. McVea had had with the operation of his hopper-bottom settlement tanks. Although he (Dr. Ardern) had no claims to be an engineer, he had had experience of the operation of the two types of tank, and he was inclined to the view that the advantage lay with the hopper-bottom type. He thought there was less danger of undue detention than with the circular flat-bottomed tank. Except on certain difficult sites the first cost was very little different, and you had no mechanical parts to operate.

With regard to Mr. Hurd's paper, it was very gratifying to find that the experimental work done in this country had been corroborated by Mr. Hurd in such a satisfactory manner, because he (Dr. Ardern) had not been absolutely satisfied that the side diffuser was an advance. The more one worked in sewage matters, the less one was inclined to dogmatise; and any valuable information, such as Mr. Hurd brought along, was to be welcomed. With respect to the question of operating costs, we had to consider what was practicable, and in this country he was afraid that such costs as would obtain as the result of using the same amount of air per gallon of sewage as was generally used in America—especially having regard to the difference in strength of American and English sewage—would render the process very unattractive to English people. If you took the Milwaukee consumption of air at $1\frac{1}{2}$ cubic feet of free air compressed to 7 or 8 lb. per gallon of sewage treated, and compared it with under 1 cubic foot free air at 4 lb. pressure, the amount employed

in the Withington plant, and with the price of power appreciably more than obtained in most places in the United States, it would be seen that the operating cost would show a very considerable increase over those at present obtaining in this country. At the same time, we had not solved the sludge problem, and if to solve that problem it was necessary to use the greater volume of air, that fact must be taken into consideration. Most plants in this country were managing by disposing of wet sludge on land, and while he agreed with Mr. Eddy with regard to the different features of many plants, not only in this country but also in the United States, he thought there were many places where the disposal of sludge in the liquid form would offer more attractions than de-watering. It was impossible to lay down hard and fast rules.

Mr. Charles H. Hurd (Indianapolis) said Dr. Ardern has asked for information as to the method of disposal of solids removed at the Indianapolis plant before aeration and the purpose of such removal and its effect on subsequent treatment.

Only the grosser solids are removed at Indianapolis in advance of aeration and the quantity corresponds to about one third of the suspended solids contained in the sewage. This separation is accomplished by rapid settling tanks, mechanically cleaned, augmented by fine screen filters. The period of subsidence in these tanks is from twenty to forty minutes, which period, I believe, is representative of English practice in the use of detritus tanks. The effectiveness of separation is due to the settling of the heavy or concentrated sewage resulting from the use of the screens.

The dehydration of the primary sludge which is continuously removed from the settling tanks is comparatively simple. It should be observed that Indianapolis sewage is extremely fresh when compared with English standards and that it passes through the clarification process entirely by gravity and without being agitated by pumps or other means. On account of the freshness of the sewage, this sludge is extremely fibrous and drains in tanks with perforated walls, in a few minutes, to a water content of from 75 to 80 per cent. It is proposed to mix this sludge, which contains about 5 per cent. organic nitrogen dry basis, with the activated sludge, reducing the total to about 10 per cent. water content by means of indirect condensing-vapour-type rotary driers.

As to the economics of this process, it is not to be assumed that the method described would prove advantageous under conditions less favourable than those which obtain at Indianapolis. Demonstration tests prove conclusively that effective aeration may be carried on at higher rates and with the use of less air and with less difficulties in operation with sewage in which the heavier solids have been removed by pre-settling. This method adds flexibility to plant operation and accomplishes the purpose, without septicization, of the detritus tanks in other systems. The construction cost of the pre-treatment plant at Indianapolis is but 3 per cent. of the total cost, and until more successful methods have been developed for filtering activated sludge, we believe this more direct means entirely justifiable.

Unquestionably, the activated sludge treatment of sewage is the most sanitary process which has yet been devised for sewage purification. Its advantages are so pronounced, it is with reasonable certainty that we feel that any present difficulties will be overcome. The Indianapolis plant is located in the central area of a 230 acre recreation park. The system was selected for its cleanliness, its completeness and its possibilities for agricultural purposes, in the recovery of available nitrogen.

Mr. Chalkley Hatton said that it was not correct that at Houston they emptied ten thousand pans of night soil every night, but they had ten thousand houses in the outskirts of the city without sewage facilities. These had dry pans, the contents of which were collected, probably twice or three times a week, and taken to a dumping station which was in the heart of the city, and dropped at night over the screens. Thus there was a large accumulation at that particular period of the twenty-four hours. The dry sludge at Houston was produced by adding to the sludge (which was about 98 per cent. water), SO_2 in certain quantities, and then passing the sludge, after it was acidified, through a cloth filter such as was used in paper manufacturing industries. There it was reduced to about 76 to 80 per cent. moisture and afterwards taken into a drier of the buckeye type. The sludge took forty minutes to go through the drier, came out with 10 per cent. to 12 per cent. of moisture, was partially pulverised, packed and shipped.

Madame Wibaut, of Amsterdam, had asked about the possibility of infection through discharging wet sewage or activated sludge upon land, and he might say in answer to that question that in Milwaukee they had taken up the question with the United States Public Health Bureau. After a very long investigation they had been advised that unless they dried their sludge to 10 per cent., and thus sterilised it, they could not expect the United States Health Service to help them in any way to have their sludge utilised as a general fertiliser. The Health Service would not countenance the discharge of wet or undigested sludge upon land, especially where kitchen vegetables were grown, and it regarded the practice as more or less a danger to cattle. Where certified milk was produced, the practice would not be allowed, so that the Health Service's advice was that Milwaukee should not attempt to market the wet sludge in any way, but should have it sterilised by drying. This was done; and, so treated, it was fit for any kind of fertiliser. One other question had been asked, whether the wet sludge if discharged upon the land would not give more plant food than did the dry. The answer was that it would not. In the first place, the fact must not be overlooked that in the wet sludge there was probably only 2 per cent. of solid matter, real nitrogenous matter, in which the nitrogen was available. There was much better availability with the dry sludge. You could not get more than from 30 per cent. to 32 per cent. of availability out of even the small amount of nitrogen contained in the volume of wet sludge, whereas out of the dry sludge you could get a total availability of from 70 to 75 per cent.

The Conference Adjourned.

COLLOID CHEMISTRY AS APPLIED TO ACTIVATED SLUDGE.

By John Arthur Wilson,

Consulting Chemist, Sewerage Commission of Milwaukee, Wisconsin.

Until recently, the one weak point in the activated sludge process was the extreme difficulty experienced in de-watering the waste sludge produced during the winter. Sludge obtained from very cold sewage could not be de-watered satisfactorily by simple filter pressing. But the problem of de-watering such sludge economically has now been solved through the application of colloid chemistry at the Milwaukee Testing Station. Lack of space prevents giving more than the briefest mention of the most outstanding points leading to the solution of the problem.

In the aeration tanks, activated sludge is built from the solid components of the sewage in a manner apparently analogous to the building of tissues in the animal body. When the temperature of the sewage in the aeration tanks is lowered, this building process is correspondingly retarded and the solid matter of the sludge is left in a more finely divided state. In order to effect purification of the sewage, it is necessary for the sludge particles to grow to such size that they will settle out quickly upon standing, thus permitting the purified water to be decanted off from the settled sludge. At all times of the year, the sludge produced in the aeration tanks was found to be coarse enough to permit satisfactory separation into clear effluent and a thick sludge containing about 2 per cent. of solid matter.

During the winter, however, it was found that the solid particles of the settled sludge were too small to permit satisfactory filter pressing; the finely divided matters would pass into the interstices of the filter cloth and clog, or blind, it, thus preventing further removal of water, even under high pressures. The problem was to find a simple method of causing the smallest particles to unite to form others large enough to avoid blinding the filter cloth. Changing the degree of sub-division of a material is eminently a problem of colloid chemistry.

In the summer, when the temperature of the sewage is about 70°F., the waste sludge can be de-watered by filter pressing without any special treatment. In the winter, when the sewage has a temperature as low as 45°F., it takes about twenty times as long to filter a given quantity of sludge as it does in the summer. The problem thus resolved itself into

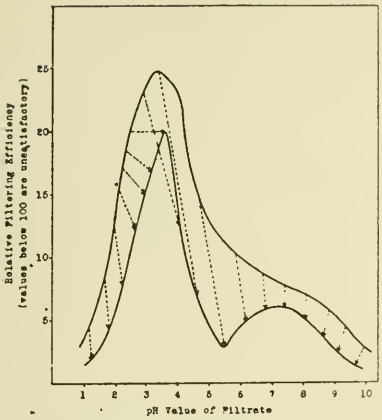


Fig. 1 - Effect of change of pH value upon the relative filtering efficiency of winter sludge. The upper curve represents series filtered 16 minutes after acidifying, the lower curve a series filtered 24 hours after acidifying, dotted lines connect points representing samples of sludge receiving identical treatment.

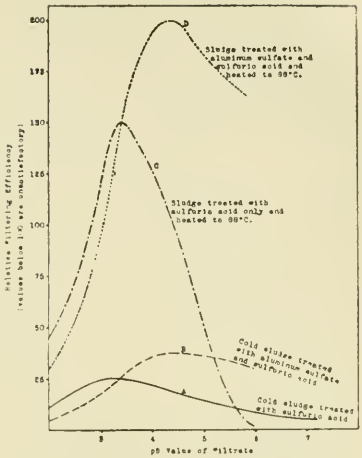


Fig. 2 - Effect of change of pH value upon the relative filtering efficiency of winter sludge treated in different ways.

finding a means of increasing the size of the sludge particles in February to such an extent as to increase the rate of filtration under standard conditions twenty times.

As produced, the sludge particles are negatively charged electrically. This electrical charge opposes the union of small particles to form larger ones. Much of the sludge consists of protein matter, which assumes a positive electrical charge in strongly acid solutions and a negative charge in alkaline solutions. With increasing electrical charge, either positive or negative, the sludge particles tend to break up into smaller and smaller particles. Conversely, with decreasing electrical charge, the particles tend to unite, forming larger ones. Obviously an ideal situation is created by so regulating the acidity as to make the electrical charge equal to zero. By adding increasing amounts of acid to the sludge, the value of the negative electrical charge is decreased until it reaches zero. With further addition of acid, the sludge acquires an increasingly large positive charge. The point at which the sludge has no electrical charge is called its *iso-electric point.* This was found to have the same value for all sludge encountered at Milwaukee, regardless of apparent variations in composition of the raw sewage. The iso-electric point of Milwaukee sludge is obtained by adding acid enough to make the *pH value equal 3.4. (On the pH scale 7.0 represents a neutral solution, values above 7.0 increasing alkalinity and values below 7.0 increasing acidity.)

* pH Value. This term is less frequently met with in the literature of sewage in England than it is in America, and a desire has been expressed for a definition of it.

The pH value of a liquid or semi-liquid is a measure of its "hydrogen ion concentration," that is to say of the number of the free hydrogen ions which it contains. It has long been known that the acidic properties of a liquid are not strictly dependent upon the amount of acid which they contain but rather upon the amount of hydrogen ions. Water contains 1 gram of hydrogen ions in 10^7 litres and is said to have a pH value $= 7$. Acid liquids have a lower value than this and alkaline liquids a higher value. The pH value of a liquid is thus a measure of its acidity or alkalinity and as shown by Mr. Wilson it can be adjusted by the addition of small quantities of acid or alkali.

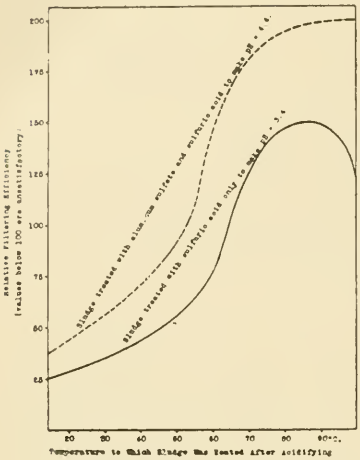


Fig. 3 - Effect of change of temperature upon the relative filtering efficiency of winter sludge previously treated with aluminum sulfate and sulfuric acid or with sulfuric acid alone.

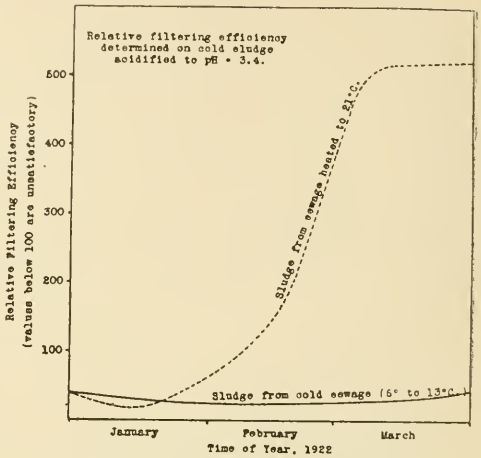


Fig. 4 - Effect of temperature of the raw sewage upon the relative filtering efficiency of the activated sludge produced.

The simple addition of sulphuric acid to the waste activated sludge to lower its pH value from 7.4 to 3.4 caused it to filter at five times its normal rate. In other words, a single filter press could be made to do the work of five presses by acidifying the sludge before pressing. This, however, did not give a complete solution of the problem because an increase of twenty times in the rate of filtration was necessary in the case of February sludge.

Another powerful means generally recognised in the field of colloid chemistry for bringing about the coagulation of a material is to add a second material having a high electrical charge of sign opposite to the one on the material to be coagulated. Since the sludge was negatively charged, the logical material to use was aluminum sulphate which is plentiful and cheap and furnishes colloidal alumina carrying a high positive electrical charge. The most efficient method of using the aluminum sulphate is to add a relatively small quantity to the sludge followed by enough sulphuric acid to bring the aluminum-sludge compound to its iso-electric point. By adding 0.25 ounce of aluminum sulphate per gallon of 2 per cent. sludge followed by sulphuric acid to reduce the pH value to 4.4, the rate of filtration was increased eight times, an amount still insufficient to permit the economic de-watering of February sludge.

When a colloidally dispersed material is brought to its iso-electric point, coagulation is accelerated by the application of heat. The rate of filtration of sludge kept at a pH value of 3.4 with sulphuric acid was found to increase with rise of temperature up to 180°F. In some cases, the sludge appeared to be decomposed by boiling, which interfered with the simple action of coagulation, but no such difficulty was experienced with temperatures below 180°. By heating the sludge to 180° after acidifying,

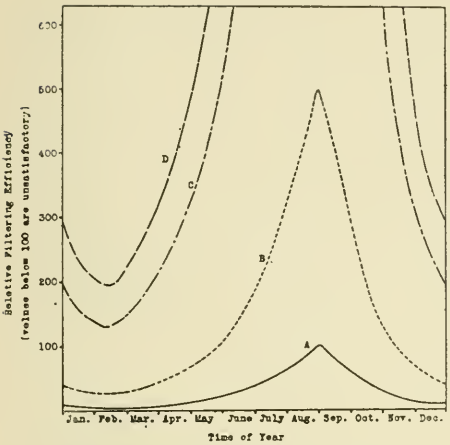


Fig. 5 - Seasonal changes in the relative filtering efficiency of activated sludge treated in various ways. A. cold sludge not treated. B: cold sludge treated with sulfuric acid to make pH = 3.4. C: Sludge acidified to make pH = 3.4 and then heated to 88°C. D: Sludge treated with aluminum sulfate and sulfuric acid to make pH = 4.4 and then heated to 88°C.

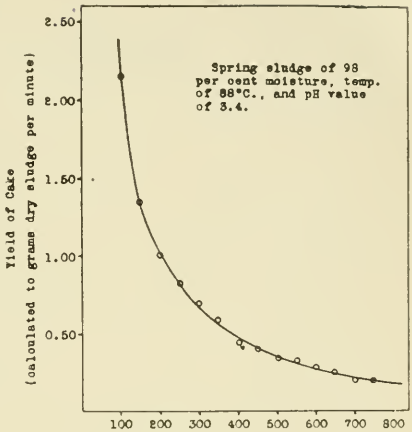


Fig. 6 - Showing how yield per unit of time is affected by the amount of sludge applied to unit filter area.

the rate of filtration was increased thirty times, an amount greatly in excess of that required for the economic de-watering of February sludge. The treatment with aluminium sulphate and sulphuric acid to make the pH value 4.4, followed by heating to 180°, caused an increase in rate of filtration to forty times that obtained with untreated sludge.

The application of heat proved of value, as might have been expected, only when the acidity was so adjusted as to keep the sludge near its iso-electric point. When untreated sludge was heated, it then filtered at a markedly decreased rate. It is important to recognise, in practice, that acidification must precede the heating operation in order to get the most efficient operation. Heating untreated sludge apparently causes the sludge to break up into particles of smaller average size. Another factor tending to do this same thing, thus greatly retarding filtration, is septic action. It was found that this action proceeds most rapidly at a pH value of 5.5 and that the pH value of untreated sludge tends to shift from 7.4 towards 5.5, if allowed to stand without aerating in a warm place. Building sludge in the aeration tanks proceeds best at a pH value of 7.4; and the coagulation of sludge for filtering is most effective at a pH value of 3.4, but intermediate pH values are to be avoided, especially in the vicinity of 5.5.

A very remarkable finding was that the percentage increase in rate of filtration obtained by each different treatment is independent of the initial rate. If one sample of untreated sludge required 120 minutes to filter, the acid-heat treatment would reduce this time to 4 minutes, while, if the untreated sludge filtered in 60 minutes, the acid-heat treatment would reduce it to 2 minutes.

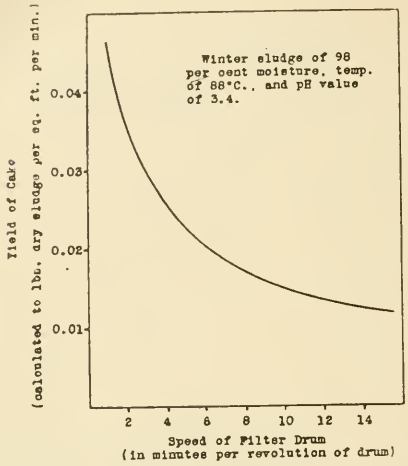


Fig. 7 - Showing how the efficiency of the Oliver filter is decreased by lowering the speed of the filter drum.

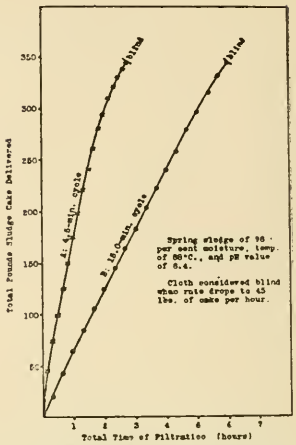


Fig. 8 - Showing how the yield of cake varies with the time of filtration until the filter cloth becomes blind. A: using a drum speed of 4.5 minutes per revolution. B: using a drum speed of 15.0 minutes per revolution.

Another important factor in filtering sludge is the amount of sludge applied to unit area of filter cloth. The average rate of filtration decreases rapidly as increasing amounts of sludge are applied to unit area. For example, in a specific case, doubling the amount of sludge per square foot of filter resulted in multiplying the total time of filtration by four, cutting the running efficiency of the filter in half. Quadrupling the amount of sludge applied multiplied the time to filter by sixteen, the efficiency being reduced to one-quarter. Because of the importance of controlling this factor, it was found much more satisfactory to use a rotary, vaccuum filter of the Oliver type.

One frequently hears of apparent discrepancies between theory and practice or between laboratory tests and large scale operations. But, where these occur, it is probable that some important variable factor has been left uncontrolled or possibly has not even been recognised. It may prove of value to cite an example of such a discrepancy and the method by which it was overcome.

By subjecting the sludge to a certain treatment, an increase in efficiency of filtration of about 100 per cent. was effected when the test was made in the laboratory apparatus. But when the same treatment was applied to the sludge to be de-watered by the large Oliver filter, the increase in efficiency was only about 40 per cent. In the laboratory a fixed quantity of sludge was applied to unit filtering area, but in the plant the drum of the Oliver filter was rotated at constant speed and the filter cloth allowed to pick up as much sludge per unit area as it could. Because of the improvement in rate of filtration of the sludge brought about by the special treatment, the filter actually picked up a correspondingly greater

amount of sludge per unit area, introducing a variable factor tending to reduce the filtering efficiency, with the result that the Oliver filter showed only a fraction of the improvement obtained in the laboratory, where this factor was kept constant. However, when the filter drum was rotated at such speed that it always picked up the same quantity of sludge per unit area, the Oliver filter showed exactly the same increase in efficiency that was found with the simple laboratory filters.

Using the Oliver filter, the amount of sludge picked up per square foot of filter cloth is determined by several factors, including the drum speed, the degree of submergence of the drum in the sludge bath, the per cent. of solid matter in the sludge, and the condition of the sludge, especially as to average size of sludge particles. The rate of filtration is determined by the amount of sludge picked up per square foot and also by the extent to which the filter cloth has been clogged, or blinded, by finely divided sludge. The blinding of the Oliver filter is a function of the condition of the sludge and the quantity applied per square foot since the last cleaning of the cloth and is practically independent of the time taken to apply this quantity. An example of this follows.

Two filter runs were made with sludge from the same tank. In one case the drum was made to revolve once in 4.5 minutes ; in the other once in fifteen minutes. In each case the cloth was thoroughly washed before the run was started and the drum was stopped as soon as the rate of delivery of cake fell to 45 lb. per hour, which was taken as the blinding point. In each case, blinding occurred when 350 lb. of cake had been delivered, but with the higher drum speed this was accomplished in three hours against six hours for the lower speed. By tripling the drum speed, the quantity of sludge picked up per revolution was reduced to two-thirds, but the greater speed gave a net increase of about 100 per cent. in yield per unit of time. The amount of sludge which the filter can deliver before becoming blind varies with the condition of the sludge, being greatest in September and least in February for sludges otherwise treated the same.

To summarise very briefly : By applying what has been learned of the effect of pH value, temperature, and polyvalent ions upon colloidal behaviour in general to the specific problem of de-watering activated sludge and further by introducing certain broad principles of filtration, it has been shown how to increase the efficiency of this operation by about 4000 per cent., thus removing the one weak point from what was otherwise the most efficient process known for purifying sewage.

The seven illustrations given in this paper are reproduced from lantern slides shown at the Conference.

ELASTICITY OF THE ACTIVATED SLUDGE PROCESS.

By Joshua Bolton,

Manager, Sewage Works, Bury, Lancs.

It has generally been supposed that the activated sludge process is not of an elastic nature, and that great care, constant agitation, and aeration, is essential. An unavoidable stoppage of power to our 50,000 gallons unit gave rather startling evidence and demonstrated factors which I had not previously realised.

Before dealing with our experience, a description of the plant in use would not be out of place.

The plant installed is the "Simplex" aeration process made by the Ames Crosta Sanitary Engineering Co., Ltd., Nottingham, and a working model can be seen at the British Empire Exhibition in the exhibit of the Ministry of Health, which will be found in the annex to the government building.

The plant consists of a tank 18 feet deep, 24 feet diameter. The bottom is cone-shaped at an angle of 37½ degrees increased to 60 degrees at a distance of 2 feet from the circumference of the tank. A light vertical tube 3 feet in diameter is fixed in the centre of the tank, resting on feet 6 inches from the bottom of the tank, thus giving a free access for the mixture of activated sludge and sewage to enter the bottom of the tube and pass up to the top. At the top of the tube a revolving cone 6 feet in diameter is suspended, with an opening 3 feet in diameter to correspond with the diameter of the vertical tube. This revolving cone is fitted with suitable vanes, and is suspended from a vertical shaft mounted on ball bearings and driven by suitable gearing. When the cone is set in motion, the liquid is thrown out in film formation, and as the film of liquid strikes the surface of the liquid in the main body of the tank, millions of bubbles are formed and the agitation is sufficient to thoroughly aerate the liquid, which, of course, is a mixture of activated sludge and sewage. As the liquid is thrown out from the revolving cone, the liquid from the bottom of the tank rushes up the central tube, and thus a constant and thorough circulation is obtained. The liquid which is thrown out from the cone strikes the surface of the main body of liquid and gives an impetus to it which creates a spiral motion in the tanks, the spiral descent ensuring a thorough contact between the sludge and sewage.

A novel arrangement is provided by the construction of a thin shell wall which divides the tank into two compartments, an inner circle and an outer ring. The shell wall protrudes above the surface of the liquid, but terminates about 4 feet from the bottom of the tank. This shell wall divides the tank into two compartments, the inner circle being the agitating area, and the outer ring being the quiescent or settling area. The distance between the outside wall of the tank and the shell wall can be so arranged as to give the desired ratio of settling area to agitating area.

A sill is fixed at the outside of the settling area, over which the purified effluent passes.

The ascending velocity of the water in the settling area is less than the descending velocity of the sludge ; and the sludge settles down and passes automatically into the aerating area to be re-circulated.

A draw-off pipe is fixed in the side of the tank, the outlet being about 2 feet below the surface of the tank, the pipe being led to the bottom of the tank on the inside, to permit excess sludge to be drawn off from time to time.

The tank works continuously during ordinary times with a loss of head not exceeding 3 inches, and no power is expended on pumping return sludge. It is found advantageous to stop the tank for a short period before any surplus sludge is drawn off, as this allows the sludge to settle and become more dense, thus obviating drawing off a too watery sludge.

The plant at Bury has been in operation over three years, and during the first eighteen months it gave good results, but occasionally there was a falling off in the results when various trade wastes, from the gas works and fellmongers, came down the sewers. The circulation at this period was at the lowest point, the power used being only twelve horse power per million gallons treated. The circulation and aeration had to be increased, increasing the power to eighteen to twenty horse power per million gallons treated and whilst using this power the results have been constantly brilliant and trade wastes have given no trouble.

Owing to circumstances over which we had no control, our power supply was shut off for a period of four days, and we had grave anxieties as to what would happen to the sludge. The water in the aerating area and settling area remained brilliantly clear, and when the power was available after four days stoppage, the plant was put in motion and the contents circulated for three hours. A little odour was noticed at the start but this rapidly disappeared. Sewage was turned into the tank and good results obtained immediately. From later experience I am of opinion that the sewage could have been turned on at once without the three hours' circulation and aeration, and good results obtained.

The activated sludge process is now well established and its advantage over other methods lies in the economic factor. Each reduction in the power factor is of importance, the more the power can be reduced the greater is the advantage over other systems.

One of the points that have struck me as wasteful in power has been the constant working of the machines during periods of low night flows. Our experience having shown that a lengthy stoppage did not jeopardise the process, I arranged to have one of our tanks shut off for a period of eight hours each night. The results, instead of deteriorating, were actually better.

The table of analysis gives the results over a period of eleven weeks, the flow being stopped and also the machinery for a period of eight hours each evening. The flow to one unit was increased to take the sewage which was shut off from the other unit.

TABLE NO. I.

Showing summary of results whilst plant was shut down eight hours per day.

	Quantities stated in parts per 100,000.					
	Crude sewage.			Effluent.		
	Highest.	Lowest.	Average.	Highest.	Lowest.	Average.
Oxygen absorbed.						
4 hours test	12.00	1.88	6.40	1.20	0.53	0.80
Ammonias.						
Free and saline ..	3.10	1.85	2.27	1.88	0.63	1.24
Albuminoid	2.44	0.31	0.73	0.14	0.07	0.10
Nitric nitrogen	—	—	—	0.63	0.29	0.43
Dissolved oxygen taken up in 5 days	—	—	—	1.42	0.50	0.94

	Purifications.		
	Highest.	Lowest.	Average.
Oxygen absorbed.			
	Per cent.	Per cent.	Per cent.
4 hours test	95.5	61.3	87.5
Ammonias.			
Free and saline ..	82.0	13.0	45.4
Albuminoid ..	93.1	66.6	86.3

Duration eleven weeks.

The fact of the effluent being better led me to conduct experiments with simple contact with activated sludge and sewage. In these experiments samples of crude sewage were taken and placed in a vessel containing 15 per cent. by volume of activated sludge in an active condition. The vessel was tilted a few times so as to thoroughly mix the liquid and sludge, then the vessel was allowed to stand one hour to enable the sludge to settle. From the table of analyses it will be seen that a remarkable purification takes place by simply mixing the sludge and sewage together without aeration or agitation other than what was necessary

to distribute the sludge in the sewage. When a tank is in operation and the power is shut off, the suspended sludge gradually settles to the bottom and is doing effective work during the whole of its travel down through the liquid in the tank.

TABLE NO. 2.

Oxygen absorbed. 4 hours test.

	Quantities stated in parts per 100,000.		
	Crude Sewage.	Effluent.	Purification. Per cent.
Highest	9.20	4.60	77.0
Lowest	3.50	1.31	50.0
Average	5.40	2.15	60.2

Period of test 2 weeks.

So satisfactory were the results obtained whilst the tank was stopped each night that I was inclined to think that purification might take place when sewage was in contact with active sludge even without aeration or agitation. To test this theory samples of sewage were placed in a vessel and 15 per cent. of active sludge was passed slowly down a tube to the bottom of the vessel so as not to create a disturbance or allow bubbles of air to enter. The vessel was allowed to stand undisturbed for eight hours, and the supernatant water was then decanted off for analysis.

Table 3 gives the summary of the results, and here again some remarkable evidence is obtained, for it shows that when a tank is stopped and after the sludge has settled to the bottom purification is still taking place.

TABLE NO. 3.

Oxygen absorbed. 4 hours test.

	Quantities stated in parts per 100,000.		
	Crude sewage.	Effluent.	Purification. Per cent.
Highest	7.40	3.93	68.9
Lowest	1.83	0.80	45.3
Average	4.60	1.81	60 6

Duration of test 3 weeks.

A further set of experiments were carried out, giving a gentle agitation of active sludge and sewage for a period of one hour, and the results are given in Table 4.

TABLE NO. 4.

Oxygen absorbed. 4 hours test.

	Quantities stated in parts per 100,000.		
	Crude Sewage.	Effluent.	Purification. Per cent.
Highest	12.00	4.43	78.2
Lowest	2.85	1.10	55.2
Average	6.56	2.26	65.5

Period of test 2 weeks.

The Birmingham school had previously done valuable work on these lines, and our experiments were carried out to see what effect this method had on the Bury sewage. Our results confirmed the Birmingham views; and for a town where percolating beds are already constructed, and where it is desired to lessen the work on the beds and give greater efficiency, this short period of aeration offers great possibilities. The subsequent settling and re-aeration of sludge adds a little complication.

A useful comparison may be made between chemical precipitation and short-period aeration. When compared with efficient chemical precipitation, the results from short period aeration are infinitely better and much cheaper.

On one occasion whilst the surplus sludge was being drawn off from the tank, a mistake was made and an excessive amount of sludge was drawn off, which reduced the quantity in the tank to below 5 per cent. Instead of the results going off, as we naturally expected, they remained constant, and the plant was worked for a period of six weeks with 5 per cent. of sludge; and from Table 5 it will be seen that the results were constantly satisfactory.

TABLE NO. 5.

Oxygen absorbed. 4 hours test.

	Quantities stated in parts per 100,000.		
	Crude Sewage.	Effluent.	Purification. Per cent.
Highest	11.10	1.33	91.8
Lowest	4.10	0.67	70.1
Average	7.78	1.11	85.6

Period of test 6 weeks.

The volume of sludge that can be used has a wide range, and volumes from 5 per cent. to 40 per cent. have been used with good results ; but the most satisfactory volume for the Bury sewage is from 10 per cent. to 15 per cent. In cases where short periods of aeration are adopted and the sludge re-aerated, the economy effected by the smaller volume of sludge to be aerated must be considerable.

A further experiment was conducted to ascertain how long sludge could be kept without aeration before it became foul. A sample of sludge in an active condition was mixed with a sample of sewage and allowed to stand for 24 hours. The supernatant liquid was then decanted off and another sample of sewage was put on and gently mixed so as to avoid aeration. The procedure was repeated daily, and it was six days before the sludge developed an offensive odour and it will be seen from the table that considerable purification took place daily.

TABLE NO. 6.

Oxygen absorbed. 4 hours test.

Quantities stated in parts per 100,000.

	Crude Sewage.	Effluent.	Purification. Per cent.	Remarks.
1 day ..	6.00	2.57	57.1	No smell.
2 days ..	6.00	2.71	54.7	,, ,,
3 ,, ..	6.80	3.50	48.5	,, ,,
4 ,, ..	8.00	3.36	58.0	,, ,,
5 ,, ..	8.20	3.57	56.5	Slight offensive odour.

These experiments were carried out not with the idea of scientific research, but to see how the process would behave under rough usage. Small authorities will not be able to pay for highly trained managers and it is probable that non-technical men may be in charge of small works and the care bestowed not all that could be desired.

I think the experiments have demonstrated that the process is very elastic and will stand shocks, which ought not, but may be applied to it.

THE ACTIVATED SLUDGE PROCESS IN INDIA AND THE EAST.

By Professor Gilbert J. Fowler.

In response to the Secretary's request, a few descriptive notes on the installations for sewage purification by the activated sludge process in India and the East are submitted for the information of Sanitary Engineers.

So far as the writer is aware, the only installations actually in operation east of Suez are at Jamshedpur, near Calcutta, at the Indian Institute of Science, Bangalore, India, and in Shanghai. They are all designed on what is known as the " diffused air " system. An installation was under construction some years ago for the Sibpur Engineering College, Calcutta, but owing to financial stringency has not been completed. Equipment has been provided for an experimental plant, sanctioned by the Bombay Development Secretariat, for Ambernath, an industrial settlement, a short distance from Bombay, and construction work is expected to begin shortly.

The application of the process to the purification of the sewage of Hankow and of important towns in the Federated Malay States has been under consideration, following preliminary official reports by the writer on the general situation as regards sewage disposal at these centres.

JAMSHEDPUR.

The Jamshedpur installation was constructed by Mr. F. C. Temple, Town Engineer, in consultation with the writer, and is intended as a first unit in a much larger plant. It is designed for 3,000 people at 38 gallons per head, giving a daily dry weather flow of rather more than 100,000 gallons. The tanks were arranged to give six hours' aeration in three units, each designed to deal with 50,000 gallons on the basis of six hours' aeration, thus giving a margin of 50,000 gallons over the dry weather flow of 100,000 gallons.

From the first the works have given excellent results, though they have regularly received more sewage than they were designed to treat. The sludge and effluent have been used to irrigate what was practically desert land, and some 40 to 50 acres have been brought under luxuriant

cultivation, the chief crops being market-garden produce and sugar cane. The land, originally of a barren sandy nature, has acquired a good tilth. The operation of the plant has been in the hands of Mr. V. N. Sarangdhar, Town Chemist of Jamshedpur, and a former student of the writer. An official report of the work of the installation, especially from the agricultural point of view, is expected to be published shortly by the Jamshedpur authorities.

INDIAN INSTITUTE OF SCIENCE, BANGALORE.

The installation at the Institute of Science was designed for 200 people at 30 gallons per head. As a matter of fact, about 450 people contribute to the sewage which should reach the tanks, but chemical analysis indicates that only a certain proportion of the urine enters the sewers.

The plant has been used for experimental work of various kinds, under the personal supervision of the writer, and in consequence the conditions have been made at times purposely unfavourable, particularly in regard to air supply. On the other hand, the plant being adjacent to an old installation of septic tank and filters, which it was designed to supplement, it was possible to divert the sewage flow into its former channel, and adjust conditions as desired without serious detriment to the ultimate effluent. The conditions of working were, therefore, in this respect less stringent than might be the case in general practice.

Inadequate air supply has been found to be the cause of many difficulties. It is possible, for a certain period, to obtain quite a good effluent with an air supply about half the amount which experience has shown to be necessary. It has been found, however, that in course of time, under such conditions, banks of unoxidised sludge form, and the qua ity of the effluent deteriorates rather suddenly, " bulking " of the sludge takes place, and the whole process is disorganised. Moreover, insect larvæ, particularly of *chironomus*, appear in quantity in the slowly moving sludge and completely alters its physical characteristics.

With an adequate air supply, viz., for a plant of this description, 50 cubic feet of free air per minute, none of these troubles occur, and an excellent effluent is constantly obtained.

" Bulking " has been found to be due to filamentous bacteria rather than to protozoa, although numerous forms of the latter may be present. The experiments have been of great interest as showing the close analogy which exists between the forms of life in activated sludge and in arable land, and their variation with conditions of aeration, temperature, and season. Moreover, by treatment of samples of the sludge with certain differential antiseptics, e.g., oxazine dyes, it is possible to destroy numerous protozoa, with consequent increase in the development of bacteria.

The effluent and some of the sludge have been used for irrigation purposes in the immediate vicinity of the installation and excellent crops of cabbages, chillies, vegetable marrows and other market produce have been raised on what was formerly jungle land.

No nuisance of any kind has arisen either from the tanks or the irrigation area.

It has been found that the routine oversight of the plant, including the admission and shutting off of the sewage and the turning on or off of the electrical power, can be entrusted under general instructions to illiterate Indian subordinates.

Valuable experimental work has been done both on the working scale and in the laboratory on the fermenting together of leaves and house refuse and activated sludge, with production of an excellent manure, rich in humus. Certain scientific conditions for success have yet to be worked out in detail, but there is good reason to hope that on these lines it will be possible to solve at once the problem of disposal of activated sludge and of house refuse.

SHANGHAI.

The City of Shanghai is built on an absolutely flat plain, intersected by creeks, and draws its water supply from the Whangpoo into which any sewage effluent might ultimately flow.

Land is expensive and difficult to obtain. The City has been accustomed to receive a revenue of £40,000 per annum by the sale of night-soil. Nevertheless, under the closely packed conditions of a modern city, an insistent demand arose for a water-carriage system. At the request of the Municipal Council the writer visited Shanghai in 1918 and reported generally upon the situation and continued as Consulting Adviser to the Municipality for five subsequent years. During that time, under the direction of the then Commissioner of Public Works, Mr. C. H. Godfrey, and his successor, Mr. C. Harpur, a scheme of sewerage and sewage disposal has been developed, which is described in successive annual reports of the Municipality.

At an early stage in the preparation of the scheme Mr. Percy Gaunt, formerly on the scientific staff at the Davyhulme Works, Manchester, England, was appointed Chief Sanitary Chemist and is responsible for the chemical and bacteriological side of the work.

It has been decided to construct three disposal works on the activated sludge system. Data for these have been obtained from small experimental tanks treating various types of sewage.

The works for the Central area are in course of construction, the first set of aeration and sedimentation tanks having been completed in 1923 and put into operation with satisfactory results.

It appears that the Chinese cultivator willingly makes use of activated sludge as a fertiliser.

The problem of house refuse disposal is becoming acute in Shanghai as in other large towns and the provision of destructors or pulverisers, preferably the latter, is under consideration. It may well be that the process of combined disposal of activated sludge and refuse referred to in a previous paragraph may here find useful application.

In conclusion, it may be stated without hesitation that the activated

sludge process has shown itself applicable to tropical conditions, both for large towns and for small communities, and the hope may be expressed that it will play its part in the increasingly difficult and important problem of food supply for the large and increasing populations of the East.

In this connection some paragraphs may be quoted from the Report by the Commission on Profiteering, Straits Settlements, 1921 :—

> "The supply of vegetables is one of the most serious of our food problems. Reduced to its simplest forms the supply of vegetables is commensurate with the supply of manure. . . . . The system of water-borne sewage is, in towns with an unlimited water supply, recognised as the best method of sewage removal and it also lends itself to the utilisation of the sewage for fertilising purposes by the formation of sewage farms. . . . . We recommend the immediate establishment of sewage farms, and we do so the more readily because there are large tracts of land easily within the radius of a sewage system which could be converted into vegetable gardens."

By the adoption of the activated sludge process as a preliminary to land treatment it has been demonstrated that sewage farms may be established without nuisance and with the least loss of the manurial value of the water-borne sewage.

EXPERIENCE IN DE-WATERING ACTIVATED SLUDGE.

By Langdon Pearse,

Sanitary Engineer, the Sanitary District of Chicago.

The experience in the United States on de-watering activated sludge has been acquired principally in testing stations built at Chicago (Tannery, Packingtown and Corn Products) Indianapolis, Milwaukee, Urbana, (Illinois State Water Survey) and New Britain, Conn., and at actual operating activated sludge plants at Houston (Texas) and Chicago (the Sanitary District) each of which have two plants in operation (Tables 1 and 2).

The difficulties of dewatering are chiefly due (1) to the physical condition of the solids which retain very tenaciously the water (2) to the large volume of sludge to be handled and (3) to the importance of removing practically all the solids from the sludge.

Briefly the problem is to take a sludge containing from 98.5 to 99.5 per cent. water and reduce the water content to 80 per cent. or less, the resulting cake being then heat dried to a moisture content of 10 per cent. Various types of apparatus or treatment have been tried. These may be classified as follows :—

PRIMARY REMOVAL OF WATER.

1. Air drying or prepared sand beds.
2. Filtering.
   1. Through fine wire mesh (Maclachlan).
   2. Through filtros plates.
   3. Through absorbent material.
3. Filtering with aid of additional pressure.
   a. Hydraulic pressure applied to liquid
      1. Chamber or leaf filter press.
      2. Kelly filter.
   b. Hydraulic pressure applied to bags.
      1. Worthington.
      2. Berrigan.
   c. Vacuum filters.
      1. Rotary leaf or American.
      2. Rotary drum or Oliver.

TABLE 1.

DATA ON ACTIVATED SLUDGE IN THE U.S.

Name.	Plant Data. Aeration hours.	Re-Aeration hours.	Cu. Ft. air per gal.	Parts per million. Sewage. Susp. matter	B.O.C.	Effluent. Nitrates	B.O.C.
Urbana	4 to 5		1.3	90 to 130			
Indianapolis	°6		0.6 to 1 0	190 to 310	156		
Milwaukee	°6		1.5	244			
Houston—							
North Side	2-1/2	3 1/2	1.6	192	176	1 to 16	
South Side	3-1/4	4-1/2	2/1				
Chicago, Sanitary District–							
Packingtown	9		3.5	605	990	0 to 7	33 to 112
Tannery	10		3.0	350	300 to 400*	0 to 20	
Corn Products	12		3 to 4	196	400 to 960	0 to 20	
Calumet	4		0.8 to 1.0	66 to 90	70 to 100*	10 to 3	
DesPlaines.	4 to 5		1.2	190	122*	4 to 12 Avg. 8.9	8.5 to 17.0

° Design basis. *5 days at 20° C.

TABLE 2.

DATA ON ACTIVATED SLUDGE IN THE U.S.

Name.	Sludge from Tanks per Ct. on Dry Basis. Fixed.	Volatile.	N.	P_2O_5	Lb. per mil. gal.
Urbana			5.1	3	740 to 1150
Indianapolis					1152 to 1656
Milwaukee	37.1	62.9	4.64	2.3	2000
Houston..	37.1	62.9	4.64	1.9	
Chicago, Sanitary District—					
Packingtown	37.4	62.6	4.2	2.7	1900 to 2400
Tannery	50.6	49.4	2.2		2260
Corn Products	25	75	6.0	5.5	785
Calumet			4.5		400
DesPlaines	45	55	5.0	4	650

4. Centrifuge.
   a. Intermittent.
   b. Continuous.
5. Flotation.
6. Spraying (Bailey).

SECONDARY REMOVAL OF WATER.

1. Rotary heat dryer.
   a. Direct.
   b. Direct-indirect.
   c. Steam.
2. Travelling belt dryers.

Activated sludge de-watering is not to-day a problem of finding suitable machinery so much as of properly conditioning the sludge itself. By conditioning is meant both the control of the activated sludge process as well as any supplementary treatment given by adding chemicals with or without heat. A sludge from a system producing a well nitrified effluent (5 to 10 parts per million) works better than a sludge from a system producing a low grade effluent (under 5 p.p.m.). The moisture content of the sludge also has a bearing on its behaviour. At times it has proven advantageous at Chicago (DesPlaines) to dilute the sludge with effluent or clean water to bring the water content above 98.0 per cent.

Precipitation or sedimentation have not proven very helpful, except to reduce the first bulk of water. Seldom has the sludge gone below 97 per cent. in the Sanitary District experience.

The admixture of an inert material like fuller's earth to coagulate or hasten absorption has not proven successful and may injure the fertiliser value of the sludge by dilution. The use of garbage tankage or screenings has been suggested, to add fibre. Screenings mixed in have proven somewhat helpful at Chicago (Packingtown).

The Sanitary District has endeavoured to press activated sludge without heat. Under the conditions at Calumet and DesPlaines with cold sludge, the use of sulphate of alumina (4 to 10 lbs. per 1,000 gals. of 98.5 per cent. sludge) has been helpful and far more beneficial than sulphuric acid (3.8 to 5.3 c.c. per gal.)

At Milwaukee acid with heat has proven most productive during cold weather but sulphate of alumina has been almost as useful. The experience to date indicates the necessity of actual trial of the sludge.

WINTER *VS.* SUMMER RESULTS.

At Milwaukee, considerable difference is reported in the behaviour of the sludge in the presses, between winter and summer, which will be met by heating the sludge in the colder weather with a maximum heat in February of 155 deg. Fahr. At Chicago the efficiency of the pressing has been but slightly less in winter than summer.

COMPARISON OF PRESS TYPES.

The comparison of press types is dependent on the sludge to some extent. A comparison of the presses in use at Chicago may be of interest as typical.

Press or Filter	Filter area sq. ft.	Cake Produced. lb.	Per Ct. Moist.	Cycle Hours.
Simplex	1815	4,400	78	7
Worthington	1440	3,500	76	5
Berrigan	3520	10,000	78	8
Oliver	495	1,400	80	per hour.

AMOUNT OF SLUDGE.

The amount of sludge to be handled has varied.

	Chicago. DesPlaines.	Calumet.*	Milwaukee.
Period of Aeration	4.5–5	4	
Maximum	6.8		
Minimum	2.4		
Air cu. ft. per gal.	1.2	0.8 to 1.0	
Maximum	3.2		
Minimum	0.8		
Settling, gal. per sq. ft. per 24 hrs.	1000	1540	
Maximum	250		
Minimum	1300		
Sludge—			
Gal per mil. gal. . ..	5100	2300	5000 to 20,000
Per Ct. Moisture . ..	98.5	98	
Lb. per mil. gal. ..	650	400	

*Handling raw sewage.

AIR DRYING.

Except at Indianapolis air drying has not proven desirable. In the Sanitary District tests, the Packingtown sludges dried slower than Imhoff sludge, the latter requiring from 4 to 7 days. The best air drying record to spadeable condition being 7 days on activated sludge. At Indianapolis considerable amounts of fibrous material from packing houses and canneries are present.

FILTERING.

Filtering through fine wire mesh, 30 to 60 meshes to the inch, and through paper mill, felt has been tested by the Maclachlan Company as part of a process using SO_2 as a conditioning reagent. The reports

so far are inconclusive. At Houston encouraging results were reported as against discouraging results at Pasadena. The paper mill devices have been abandoned.

Filtering through filtros plates was tried by Prof. Bartow at Urbana, on a filtering wheel with and without a vacuum. The sludge appears to have stopped the surface pores. The experiments were abandoned.

Filtering through absorbent material such as garbage tankage has been tried at Chicago. The results indicate that the tankage acts as a sponge. Consequently the retention of the water negatived any result.

FILTERING WITH AID OF ADDITIONAL PRESSURE.

Additional pressure is created by hydraulic pressure applied to the liquid forcing it into the filters chamber or applied to the sludge in bags, and by vacuum on the effluent side of the filtering medium.

Where the hydraulic power is applied to the liquid, chamber or leaf filter presses have generally been employed. Various types of leaf have been tried at Milwaukee, using drainage surfaces made with grooves or pyramidal projections, and at Chicago (Buckley) with a perforated plate drainage against the bag (120 plates each 36 by 36 ins.) Ribs were also provided. Working up to 120 lbs. per sq. in. on a cake 1 inch thick, breakage of cloths has occurred.

In the Kelly press, the filtering cloths are stretched on a frame, and set inside a cylinder, which is filled with liquid and pressure applied. The filtrate passes out through the inside of the frame. The difficulty in this type has been to produce a dry cake.

Where hydraulic pressure is applied to bags, two types have developed, both invented by J. J. Berrigan—one called the Worthington with bags filled at the top, suspended between built up steel drainage sheets and squeezed by large platens worked by a toggle joint ; the other the Berrigan, with bags filled from the bottom, suspended between built up drainage sheets of hard wood slats squeezed by pressure applied directly on the heads of the press. The Worthington press has been tried at Milwaukee. Both types are in use at Chicago (DesPlaines River), the Worthington press holding 18 bags on platens 5 by 8 ft. and the Berrigan press holding 80 to 120 bags, with platens 4 by 6 ft. The bags are filled and squeezed by dry pressure. When the cake has formed the bags are opened at the bottom. The cake drops out. The advantage of the latter form (Berrigan) is the ability to control the thickness of the press cake, and the direct squeeze, making a simple apparatus.

VACUUM FILTERS.

There are two principal types of vacuum filter on the market—differing largely in the method of supporting the filtering surface—in each case not quite half submerged. In the American filter, rotating leaves are used, supported on a heavy hollow shaft. The cloths are filled in by segments. This type is built up to 14½ ft. diameter, with 8 discs. In the Oliver type, the cloth is stretched on a built-up drum and held down

by spirally wound wire. A vacuum is produced by suitable pumps on the effluent side of the cloth, so that as the wheel or drum slowly revolves through the sludge, the solids adhere to the surface. Steam or air under pressure may be introduced during a portion of the cycle on the under side of the cloth. The cake is $\frac{1}{8}$ to $\frac{1}{4}$ inch thick with a moisture content higher than for the other presses. The Oliver filter at Chicago (Calumet) has a unit drum 11 ft. 6 ins. in diam. by 14 ft. long.

CENTRIFUGE.

So far the only tests made on centrifuges have been at Cleveland and Milwaukee. At Cleveland a few simple tests were made with an intermittent centrifuge, the sludge being placed in bags. At Milwaukee a continuous solid bowl type was tested of the Basco-ter-Meer type. This machine apparently lacked capacity to remove the solids when operating at any considerable production. When operated to produce quantity, the finer solids passed through and caused trouble in the system. A revised machine is expected for trial at Chicago (Calumet).

FLOTATION.

Flotation is an attempt with or without heat to coagulate and float the sludge to the surface for ready removal. At Fort Worth on packinghouse sludge, small amounts of acid (sulphuric) proved very effective on cold sludge, producing remarkable coagulation, with an underlying clear liquid. Such results have not been duplicated elsewhere. However, acidulation with heat was tried experimentally by the Dorr Company at Urbana and New Britain with some success. Enough acid was used to produce an acidity of 25 parts per million. Heat was then applied to raise the temperature to 50 deg. C. The process requires accurate constant control and to date has not met favour, largely because the moisture content has not been reduced below a range from 85 to 90 per cent. (New Britain), or 90 to 93 per cent. (Milwaukee). At New Britain and Milwaukee large losses of solids were reported.

SECONDARY REMOVAL OF WATER.

The preparation of the sludge cake for commercial distribution necessitates the reduction of the moisture below 10 per cent. and sizing material to pass through an eight-mesh sieve.

To reduce the moisture drying is available either by exposure to the air or by heat dryers. Air drying as such is practicable only on a very small scale with thin cake such as comes from the vacuum filters. Heat drying is practicable on a large scale with either the direct type (Buckeye at Houston) or the direct-indirect (Atlas at Chicago). In the latter the dryer shell is enclosed in brickwork. Air is admitted through parts on the dryer walls. The fuel used is generally coal, though oil is used at Houston. The dust is arrested by a cone bottomed settling tank or cyclone, followed at Houston by an air washer.

The control of the dryer is important to prevent balling of the material

to be dried. In the Sanitary District installations the sludge cake is fed into a closed system, the wet cake being mixed by a worm with dry sludge. This reduces the moisture in the material entering the dryer below 40 per cent. When running the temperature is from 1100 to 1600 deg. F., at the inlet and from 250 to 300 deg. F., at the stack. So far the best test run has been an evaporation per pound of combustible of about 9 lb. of water, but when running the evaporation drops off, averaging under 5 lb.

This apparatus is not run continuously but is kept hot and only operated by day. Hence better results are expected on a large plant. Considerable balling results which necessitates grinding, either in a Williams (hammer) crusher or in a Brown (disc) mill. Experiments are proposed on shredding or disintegration to reduce or eliminate the balling.

FILTER CLOTHS.

The filter cloth is varied by the individual preference of the various apparatus makers. In general, however, the trend is to the use of duck (about 13 ozs. twill) on vacuum drum filters and of burlap (from 8 to 12 ozs.) on bag filters and some plate presses. The burlap bags last from 30 to 45 days. The duck on the Oliver filter at Calumet has lasted about 30 actual working days.

COST DATA.

Cost data on the Sanitary District operations are not yet available, and as obtained would be of little value, because the apparatus installed has much greater capacity than is actually needed. Further the overhead of operating labour is greater for the same reasons. Labour saving devices available to a large installation were not installed to facilitate changes in methods and apparatus.

At present, however, the cost of manufacture is greater than the selling price of the finished product—$15.00 per ton. On a large scale the cost of manufacture may be brought below $15.00 per ton, as estimated at Milwaukee.

INVESTIGATIONS OF THE FERTILISING VALUE OF ACTIVATED SLUDGE.

By Victor H. Kadish,

Assistant to the Chief Engineer, Sewerage Commission of the City of Milwaukee.

When Milwaukee's Activated Sludge Sewage Disposal Plant goes into operation—serving a population of nearly 600,000 and many industries contributing huge quantities of organic trade-wastes—dry fertiliser material will be produced at the rate of 100 tons per day. A typical analysis of Milwaukee sludge, which will be practically uniform in composition at all times, is as follows :—

	Per cent.
Moisture	6.20
Total nitrogen as ammonia	7.42
Water-soluble nitrogen as ammonia	1.13
Active water-insoluble organic nitrogen as ammonia (alkaline permanganate method)	4.17
Availability of water-insoluble organic nitrogen	66.35
Total availability of nitrogen	71.48
Total phosphoric acid	2.36
Potash (water-soluble)	0.13
Fat	4.87

The ultimate economic success of the activated sludge process in Milwaukee depends upon the profitable marketing of the sludge produced ; in other words, the cost of preparation from the 96% moisture condition to final dryness must be less than the return from the sale of the finished product. With this thought in the foreground emphasis has been put first upon studying the production of a sludge having the highest possible fertiliser value, and second, upon investigating the fertilising value of the sludge actually produced by means of pot tests and field experiments under different conditions. The information obtained along these lines is herewith briefly presented.

I.

In order to de-water sludge economically by means of vacuum filtration, chemical "conditioning" is required. Phosphoric acid, sulphur

dioxide, aluminium sulphate, and sulphuric acid have all been used extensively, and their effect upon the relative filtering efficiency and the fertiliser value of the resultant sludge has been intensively studied.

Phosphoric acid was discarded only after hundreds of tests had indicated that the low percentage of recovery in the sludge made its use prohibitive from the cost standpoint. If 75% of the phosphoric acid added could be recovered, the greater cost of this chemical compared to the others would be more than offset by the increased value of the fertiliser material produced due to its enrichment with available phosphates without any material reduction in nitrogen content. There must be some means whereby economic recovery of P_2O_5 can be effected and it is hoped that further research will some day point the way.

The effect of sulphur dioxide on the sludge is no different from that of sulphuric acid ; it is cheapest per acid unit ; but it had to be eliminated because of the extremely sensitive system of acid control required.

With the field narrowed down to sulphuric acid and aluminium sulphate, attention was concentrated upon a comparison of these chemicals as to de-watering efficiency, fertiliser values and all-round cost. Disregarding other factors, aluminium sulphate invariably gives the best absolute filtering efficiencies. With temperatures below 75° F. aluminium sulphate from 75% to 100% more efficient than sulphuric acid ; but with increasing sludge temperatures it became less efficient until at 160° F. sulphuric acid only from 5% to 10% less efficient than aluminium sulphate. In the " cold " the cost of the two chemicals are equal, being about $2.00 per ton of finished material ; with increasing temperatures the cost of aluminium sulphate mounts disproportionately, being at 160° F. $6.00 per ton as against $2.40 per ton for sulphuric acid. Sulphuric acid treated sludge always gives a higher total nitrogen content. There are two reasons for this : first, aluminium sulphate dilutes the nitrogenous material of the sludge to a greater extent, and second, sulphuric acid dissolves out more of the non-nitrogenous material from the sludge, thereby giving a cake richer in nitrogen. There was no appreciable difference in the water-soluble nitrogen content nor in the nitrogen availability. Varying the pH value no marked effect on the nitrogen content, although there is a slight increase in total nitrogen with increasing acidity. A series of studies on the filtrates indicates there is slightly less nitrogen loss when aluminium sulphate is used. The temperature of filtration, however, has a more pronounced effect in this regard. At 70°—80° F. only one half as much nitrogen is lost in the filtrate as at 160° F. In all cases the nitrogen content of the filtrate is least at optimum pH—increasing on both sides of this point. Loss of nitrogen in the filtrate also increases slightly with dilution of the sludge. Sludge containing 1% solids shows about 10% more total nitrogen loss in the filter effluent than 2% sludge.

In the operation of the Milwaukee plant it is planned to filter unheated sludge during at least seven months of the year ; and it is hoped that only in cases of emergency will a temperature as high as 160° F. be

necessary. After taking all of the above findings into consideration, together with the greater ease in handling and applying sulphuric acid, the selection of this substance as the conditioning chemical was unmistakably indicated, and it was so decided.

II.

Activated sludge as a fertiliser material is a new and unknown product in the United States, and its fertilising value under different conditions has not been thoroughly established. Some small-scale scattering tests have been made in this country, but they have meant practically nothing to the fertiliser manufacturer and consumer. With large-scale production looming up it was decided to attempt the development of as broad a market as possible by means of scientifically conducted experiments in the field in comparison with those commercial fertilisers commonly used.

In view of the rather low nitrogen content of sludge, and the consequent narrowing of the shipping range, it was also felt that specialised uses for local consumption should be developed. Consequently, the Sewerage Commission in February, 1923, established a Fellowship in the College of Agriculture, University of Wisconsin, as a first step in this plan. The following is an outline of the results already obtained through the work of Mr. O. J. Noer, Fellow, under the direction of Professor E. Truog of the Department of Soils.

GREENHOUSE EXPERIMENTS.

Preliminary experiments with oats and corn, started on May 4th, 1923, showed that these crops made a marked response to sludge and that a considerable portion of the nitrogen in sludge became available during a period of two months. A series with Sudan grass, to study the effect of fineness of division on the availability of the sludge, showed that four to eight-mesh material proved as effective as ten-mesh and one-hundred-mesh material. In another extended series the availability of the nitrogen in activated sludge was compared to that in other organic materials such as tankage, dried blood, fish scrap, cotton-seed meal, dried sheep manure, etc. Sludge was applied at the rate of 1,000 lb. per acre, and the other materials to give equivalent quantities of nitrogen. Other essential elements than nitrogen were supplied in soluble form of like amount in all cases. Sludge produced decidedly better growth than sheep manure and very nearly as good growth as the other materials.

FIELD EXPERIMENTS.

In an experimental plot with rye on Plainfield sand, established May 1st, 1923, sludge was compared with sodium nitrate—being applied broadcast at the rate of 300 lb. of a 4–7–4 mixture per acre.* The sludge mixture was slightly superior to the sodium nitrate mixture.

A potato plot was established at Arena, Wis. on Plainfield sand, where nitrogen, phosphorus and potash are all required. A 4–7–6 sludge mixture was compared with a 4–8–6 commercial mixture, and mixtures

* 4% nitrogen, 7% phosphoric acid, 4% potash.

in which nitrogen was supplied from dried blood, ammonium sulphate and a combination of ammonium and sodium nitrate. The sludge mixture compared favourably with the various other mixtures.

Corn plots were also established on the same farm, comparing sludge mixtures with commercial mixtures. Applications at the rate of 200 lb. per acre produced very favourable increases in all cases.

Another corn plot was established on Carrington silt loam on the Keyser Farm near Madison, Wis. Again sludge mixtures were compared with commercial mixtures—all applied at the rate of 120 lb. per acre. In this test the increases were again marked, and the sludge mixtures actually outyielded the commercial mixtures.

LAWNS.

Numerous plots were established on lawns. Sludge was compared with sheep manure—which is largely used on lawns, both alone and in mixtures—and also with a mixture in which dried blood supplied the nitrogen. Applications were made at the rate of 12½ lb. per square rod (one ton per acre). Sludge alone proved to be superior to sheep manure in all cases. The sludge mixtures produced as good results as the dried blood mixtures. Sludge as a lawn fertiliser offers two decided advantages: there is no danger of injuring grass from burning even with heavy applications, and no objectionable odours develop when the lawn is sprinkled after sludge has been applied.

GOLF COURSES.

These experiments have been quite comprehensive in view of the early indication that sludge is an ideal fertiliser material for such purposes. Besides, golf courses are increasing in number very rapidly and should logically develop into a good market for sludge.

LYNX CLUB, MILWAUKEE.

This is a new course, construction being started in 1923. The putting greens and turf nursery were planted with stolons of creeping bent grass the latter part of August. By this method of propagation, a thin layer of stolons is spread over the surface of the green and then covered with a light top dressing consisting of soil and compost. The top dressing for green No. 10 was reinforced with sludge instead of compost. This was mixed with soil and sand and allowed to stand in pile for ten days prior to application in order to start nitrification. This treatment gave very decided results and by October 1st the stand of grass as well as the colour was much better than on an adjacent and comparable green treated in the routine way with soil and compost. In fact, Mr. G. P. Barr, in charge of developing the course, considered green No. 10 his "star" green.

Applications on the turf nursery were made in a different manner. Sludge and various mixtures of sludge with phosphate and potash were applied broadcast on one half of the nursery, at the rate of one ton per

acre, just before spreading the stolons—the sludge fertilisers being mixed with the soil with a rake, after which the stolons were planted and covered with a light top dressing of soil. The growth on these plots was markedly superior to that on the untreated half, and a clean-cut line of colour demarcation could be readily spotted as much as 400 to 500 yards distant.

BLUE MOUND COUNTY CLUB, MILKAUKEE.

This course is some twenty years old, and is now the oldest in the Milwaukee district. Late in August green No. 1 was top-dressed with a mixture of loam soil and 100 lb. of sludge. This mixture remained in pile ten days prior to applying. The response was very marked. The creeping bent grass was healthier and greener than on an adjacent untreated green.

Upon Green No. 10 sludge alone was compared with a mixture of sludge plus ammonium sulphate applied at the following rates :—

30 lb. sludge per 1,000 square foot.

15 lb. sludge + 3 lb. ammonium sulphate per 1,000 square feet.

These amounts are comparable in cost based on sludge at $20.00 per ton. Mr. Brockhausen, the greenkeeper, reported that results were noticeable on the sludge-ammonium sulphate plot 36 hours after applying ; the response to sludge alone was delayed, but after several weeks the plot had caught up with the other. Ammonium sulphate in solution is quite commonly used on golf greens, although there is always danger of burning the grass, and the effect is only temporary, due to the leeching out of the chemical. A mixture of sludge and ammonium sulphate is perfectly safe and " fool proof " is cheaper, and makes an ideal combination, inasmuch as the ammonium sulphate provides the initial stimulant, while the sludge furnishes humus and a continuing source of plant food long after the effect of the ammonium sulphate has worn off.

Unfortunately an early frost interfered with apparently promising results on potato and tobacco plots. Greenhouse experiments with carnations have been started recently, but it is too early to report results. Plans have just been completed for a comprehensive series of tests in which sludge will be compared with manure in greenhouse rose culture. It is hoped to show that sludge can replace manure to advantage in both benching and mulching soil. If this proves out, a large outlet for sludge should be opened up. During the present growing season last year's work on field crops, lawns and golf courses will be greatly elaborated. Numerous plots will be established on such truck garden crops as lettuce, onions, cabbages, tomatoes, etc. It is also planned to investigate the fertilisation of fruit trees with sludge, especially on sandy soils.

The results obtained during 1923 indicate that activated sludge has definite fertiliser value. Much of the work was largely pioneer in nature ; and by the end of this year its place and value in the fertiliser world should be definitely established.

DISCUSSION.

Dr. McGowan said that he had never made a special study of activated sludge, but he had had to deal with the question of the manurial value of other sewage sludges in connection with his work for the Royal Commission on Sewage Disposal. He had been greatly interested in the references to the de-watering of activated sludge at Milwaukee, and in the systematic work described in Mr. Wilson's paper, and he thought that if the problem had been solved there, it could be solved elsewhere. The activated sludge process had appealed to him, in the first instance, because of its conservation of nitrogen. It conserved the portion most easily assimilated by plants. There was an enormous future before it, and it looked as if America was going ahead faster than this country in the matter as it was doing also in pure chemistry.

Mr. W. H. Makepeace said he was glad to have the opportunity of being present, and especially glad of the opportunity of hearing the American gentlemen. Like other sewage works managers and engineers in this country, he had been very much fascinated by the problem, and had come up against some of the difficulties that the American engineers had mentioned. As a result of what he had heard to-day, he was quite satisfied that his difficulties were much nearer solution. He had been very much interested in the information contained in Mr. Pearse's paper with regard to the effect of the sludge under varying degrees of temperature, and, incidentally, under the various standards of purification to which the sewage was taken. The greater the purity you got in your effluent, the more nitrification you got, the easier it was to dispose of the sludge. One of the contributors of papers that afternoon had had similar experience to his own, for he had found that in the summer months the sludge settled down much more rapidly than in winter. If any of the Americans or others present cared to visit the Hanley Sewage Works, they would have some striking illustrations of the effect of dry sewage sludge on lawns and mown embankments adjoining the plant. The higher the purification you got, the higher the consumption of power, and in considering the value of the various methods of treatment, some notice should be taken of the degree of purification to which you took the sewage. You might have an effluent which would answer the requirements of the local rivers authority of one district, but would not answer the requirements of the local rivers authority of another district. In that case, to get a greater purification the power would have to be increased. Speaking of the papers generally, he could say that they had materially increased his information.

Dr. Karl Imhoff (Essen) said that in Germany they had no activated sludge plants except experimental ones. They had therefore no experience in the disposal of the excess sludge. As he saw the problem, this was the important feature of the process. Owing to its very high water-content the quantity of sludge produced was very large. It seemed to

be the idea of most experts that it would be economical to de-water that sludge by mechanical means and to produce a dry fertiliser.

In de-watering ordinary sewage sludge and producing fertiliser the best method was found to be by digestion and air-drying. Nitrogen was not the only measure of the fertiliser value of a sludge. Digested sludge with a lower nitrogen content was a better fertiliser than fresh sludge with a higher nitrogen content. Probably it was the same with activated sludge, and in any case there was no reason to avoid the digestion of activated sludge.

The best method of digesting activated sludge was to pump it into the tanks used for the preliminary treatment. Each activated sludge plant should have preliminary tanks with provision for sludge digestion—either two-storey tanks, or settling tanks and separate sludge-digestion tanks. In these tanks the activated sludge practically disappeared, since it contained only water and organic matter, which was converted into valuable gas. Two-storey tanks were better for that purpose than separate sludge-digestion tanks, especially in winter, because the digestion chambers in two-storey tanks were kept warm by the sewage flowing in the upper storey.

Dr. Ardern said he was glad to have this opportunity of expressing personally his sincere thanks to Mr. Wilson and his colleagues for their admirable and efficient work carried out at Milwaukee. He did not know of any work in connection with the problem of sewage purification which had been undertaken in such an efficient and thorough manner. He found it personally very gratifying, in view of what might be called the extreme scepticism the process had met with from many people in this country, and the great amount of doubt cast upon the difficult question of the sludge, to have such authoritative information on this particular aspect of the subject. He had had the privilege of visiting Milwaukee, and could speak from personal experience of the great value of the work that had been carried out. One or two questions he would like to ask: He saw that Mr. Wilson had come to the conclusion that the sludge particles possessed a negative charge, although later on it was not quite so clearly defined. It might be positive or negative, dependant on the pH point of the sewage, and he would like to ask whether any experimental work had been undertaken with a view to introducing a positively charged electrode and treating the sludge electrically? He was quite aware that the addition of sulphate of alumina was in effect an electrification treatment of the sludge, but he would like to ask Mr. Wilson whether he considered it within the bounds of possibility to endeavour to densify the sludge by a process in which the negative particles would be flocculated by the introduction of electrodes? Another question was whether Mr. Wilson considered that any benefit might possibly arise from the addition of inert matter to the sludge to be dealt with? Of course he saw in Mr. Langdon Pearse's paper the suggestion that very little if any success had attended the addition of inert matter of either sandy or

fibrous nature; but he would like to know whether such experiments had been tried in Milwaukee?

In dealing with the question of sludge de-watering he had been very much struck with the statements issued in connection with the Chicago work that it had been found more difficult to treat dense sludge than dilute sludge, and that they had even gone so far as to dilute a dense sludge before the addition of alumina and vacuum treatment. As he understood the position, it was that with certain very dense sludges they had not got such a good final product as when dealing with weaker sludges. In Manchester they had rather hoped that by simple mechanical means they had gone a reasonable step forward in condensing the sludge and de-watering it, because they had found they could reduce the bulk of the sludge to one-third by passing it through a slowly revolving wire-mesh cone. This statement from Chicago that, rather than being an advantage, this might be a disadvantage came as a serious blow. He had not the data before him but, so far as he remembered, the proportion of alumina to solid matter was actually very much greater in the Chicago dilute sludge than in its thick sludge, and it was quite possible this might be explanatory of the differences experienced; but he would like to have Mr. Wilson's opinion with regard to the possible advantages of preliminary densification of the sludge prior to the real attack on the problem of de-watering. With regard to Mr. Bolton's paper he (Dr. Ardern) had indicated that morning that, so far as the treatment of storm-water was concerned, there was not the slightest doubt of the elasticity of the activated sludge process; if you could treat your dry-weather flow, you could treat any storm-water you were likely to be called on to deal with. With regard to actual stoppage of the flow and consequent definite de-aeration, he would not like to speak so positively as Mr. Bolton. He did not quite follow the maximum period for which the sludge was without aeration. It was quite true that in any twenty-four hours you could leave your sludge without aeration for six or eight hours, but once the sludge had been without air or a whole day or longer, he thought it would take some little time before the plant became normal. With regard to the fertilising value of the sludge, the nitrogen in activated sludge was as valuable as nitrogen in any other form. The main difficulty was in getting the farmer to recognise that fact.

There was a question he would like to ask about Chicago. When he was in that city some three years ago they were putting down plant in which two activated sludge units were being constructed, and they were also putting down a big battery of Imhoff tanks. They were going to try side by side the results obtained from the treatment of screened crude sewage as against the results of treatment of the effluent from Imhoff tanks. What results had been obtained? So far as his own experience went, with strong industrial sewage sedimentation made very little difference to the maximum effective capacity of the plant, while it introduced much greater difficulties with regard to the de-watering of the sludge because it produced a sludge of very much smaller flocs.

Mr. Harrison P. Eddy said that, in connection with Mr. Wilson's paper, he would like to draw forcibly to the attention of the Conference the application of scientific methods to the study of the problem. It must be evident to all that the research had been carried out on a strictly scientific basis. So many tests and experiments were what might be called qualitative; they did not secure actual measurements. They, perhaps, measured the volume of sewage, and in some places the volume of air; but they did not carry the tests all the way through on a strictly quantitative basis. He thought the work Mr. Wilson had done at Milwaukee stood out pre-eminently as scientific research.

Mr. W. D. Scouller (Huddersfield) said there was one point he wanted to raise, not quite in connection with activated sludge, but with ordinary sludge. Some years ago he had found that it could not be properly pressed in the ordinary presses. It took very often three days to press, and he had tried mixing all kinds of detritus and heavy matter with this particular sludge. This had no effect in reducing the time of pressing; but by reducing the charge of acid to the sludge he had found he could reduce the time of pressing by about one-third. There was a question he would like to ask. He was still treating the sludge with acid, and he found it took about three days to get the acid into the proper pH value. If the pH value of the sludge was three to-day it might, perhaps, be five to-morrow, and so he had to make the sludge have an acidity of about 2 pH and in two or three days it came down to 3.4. Did Mr. Wilson have to keep his sludge for two or three days to get the proper acidity before he put it through his filter?

Mr. A. J. Martin (the Chairman) said that, looking back over the past twenty or thirty years, he did not remember a meeting at which they had had so many papers of such great value as those to which they had listened. That day every paper had been by a pioneer in the very front rank of sewage disposal, speaking of matters of which he had first-hand knowledge. The Conference was greatly indebted to these gentlemen for bringing before it the results of their research, experiments and practical working. Mr. Wilson's paper on Colloid Chemistry as applied to activated sludge was of the utmost value. Engineers had been accustomed to deal with sewage in the mass; and such work as Mr. Wilson and others had done in studying the internal operations which went on was of inestimable value in the solution of the practical problems that had to be dealt with. He had been much struck with Mr. Wilson's remarks as to the old absurd idea of a conflict between theory and practice. It was the business of the engineer to reproduce in practice the conditions which were found to give successful results in the laboratory.

Dr. Ardern's paper was also very interesting, and he was to be congratulated on having at last some efficient compressors at Withington. He would be able to show results better from an economic point of view than he had been able to do in the past. It was stated that the tanks

were only seven feet deep. He (the Chairman) took it that was not a matter of choice but of necessity.

Dr. ARDERN : They are adapted tanks of the greatest depth available.

The CHAIRMAN continued that he had been greatly interested in Mr. McVea's paper. He thought Mr. McVea and the municipality he served deserved the greatest credit for their courage in laying down such immense plants on a system which was then new and untried ; and they were to be congratulated on the results. Milwaukee also had led the way, and, apart from the process employed, they had carried out an engineering project of the very first magnitude in circumstances of unusual difficulty. Another point about the Milwaukee work was the thorough and painstaking investigation which had been carried out in every branch of the subject of the purification of the sewage and the disposal of the sludge. We in England were rather accustomed to deal with our work in watertight compartments, placing pumping in one, sewage disposal in another, and so on ; but at Milwaukee Mr. Hatton had dealt with his work as a whole, making use for instance, of the condensing side of his power plant to get heat for the drying of the sludge. Sanitary engineers, by viewing their work in the broadest possible way, could often get results, both as regards efficiency and economy which would otherwise be unattainable.

Dr. Ardern and his friends had produced a high-class article in the shape of activated sludge, but it had not got any further. It must be realised that if you had something you wanted to sell, the selling was no less difficult, and required no less care, than the manufacture. It was more than half the battle to put your product before the public ; and Mr. Hatton was to be congratulated on the very practical way in which he had gone to work to put his fertiliser on a commercial basis.

Mr. Hurd's paper was particularly interesting to him (the Chairman) because as long ago as 1918 he had suggested the use of spiral circulation with a view to economising power.* He was also interested in Mr. Hurd's plan for facilitating the progress of the sewage through the tanks by providing deflector surfaces at the top of his walls. Mr. Hurd said that the sewage travelled seven miles through his tanks. In chemical precipitation the precipitant travelled a few feet only ; yet it produced results physically very similar to those obtained by the activated sludge process. Why was it that in the one case the sewage had to travel seven miles and in the other only a few feet ?

Mr. Bolton had described some experiments which he had carried on in the use of activated sludge as a precipitant. By taking activated sludge and putting it into sewage, he had been able to throw down the colloidal matter without the expenditure of any appreciable amount of power. It was to be hoped that further experiments would be carried out on these lines, and that some way would be found of passing the filter of activated sludge through the sewage so as to sweep out the colloidal matter without the enormous amount of power which we now employed. Referring to

The Surveyor, 25th October, 1918.

Mr. Langdon Pearce's paper, he said he did not think that we in this country sufficiently appreciated the work which had been done in Chicago with every kind of trade refuse, and the immense amount of valuable data which had been accumulated there and which he hoped in due course would be generally available.

Mr. JOSHUA BOLTON in reply said Dr. Ardern had put a question, or had not been quite clear as to how long the tanks had been stopped. In the first case the tank was stopped unavoidably for four days, and when restarted it was in active condition in three hours, and doing its work quite well. It was this that had led him to conduct the experiments described in his paper. As he there said, the running of the plant during times of weak sewage always struck him as wasteful. In the experiment they had stopped eight hours every day for eleven weeks, and had maintained satisfactory results. Septic conditions did not set in with the sludge he had to deal with until the plant had been stopped four days.

Mr. HANSEN gave some information about the plant which Dr. Ardern had seen being installed in Chicago three years ago. He said this plant comprised thirty-two Imhoff tanks, which were presumed to give a sufficiently satisfactory effluent to meet present conditions, i.e., with the present available dilution. But it was anticipated that in the future it would be necessary to apply secondary treatment, and in order to ascertain the most suitable and economical secondary treatment certain experimental units had been established. These experimental units comprised an activated sludge plant, both with and without preliminary sedimentation, and sprinkling filters. The Imhoff tanks were so designed that they could all be converted into aeration tanks, if that was found desirable, with minimum cost and difficulty. It was merely necessary to install a false bottom, just as had been done in order to convert one of the existing tanks into an experimental activated sludge unit. There were two activated sludge tanks, with final settlement tanks, and three-quarters of an acre of sprinkling filters. The plants were operating side by side on the same kind of sewage, and it ought to be possible to get reliable data as to which was the proper method to apply for secondary treatment.

Mr. JOHN ARTHUR WILSON (Milwaukee) answered some of the points that had been raised on his paper. In reply to Dr. Ardern's first question as to whether they had attempted at Milwaukee to neutralise the electrical charge in the sludge by electrical means, he said they had done so. They had placed electrodes of high and low potential differences in the sludge; but because of the salts present in the water they got electrolysis which set up secondary reactions. If the conductivity of the sludge were extremely low, they could do what was required ; but with material containing inorganic salts it seemed impracticable to apply electrical current. With regard to inert matter they had carried on experiments with material like inert clays. They had

found this increased the rate of filtration, but only by the use of prohibitive amounts. As to whether it was more difficult to treat condensed or dilute sewage, the question could not be answered yes or no without going into conditions. If the sludge was not in perfect condition, you might find it more difficult to treat a concentrated than a dilute sludge. The test of filtration was much more sensitive than the test of the purification power of the sludge ; and it might be you would find that the sludge upon long standing seemed not to have suffered if gauged only by the appearance of the effluent. Still you would find if you carried on filtration tests that there was a decrease in the rate of filtration for every minute that the sludge stood. It filtered at a slower and slower rate, and after it reached something like a septic condition it was impossible to filter it at all. Another point with regard to sludge was that it very often happened that it was not easy to mix condensing material with the sludge, because the rate of diffusion into the solid matter of that sludge was retarded by the large amount that was there, and in a great many cases very much better results were obtained by filtering diluted than concentrated sludge ; but when we took concentrated sludge of every high quality, well aerated, and with the mixing of chemicals done very thoroughly, we actually got more efficient results with concentrated than with dilute sludge. In answer to Mr. Scouller, it was true that if you added acid to the sludge the pH value changed ; there was a slow change in reaction in the liquor for a long period of time ; but in acidifying sludge for filtration the actual reaction effect was almost instantaneous. The important thing was that the sludge should be filtered at optimum condition, not that the sludge should remain in the condition of waiting. If you added a given amount of acid, and at the end of three minutes the pH value was 3.4, at the end of twenty-four hours it might be seven. If you were going to wait twenty-four hours you must add more acid. The practice was to filter the sludge before the pH rise took place. They did not have to continue to add acid to maintain 3.4, because it was filtered practically immediately after the application of the acid.

The Chairman concluded by asking for a vote of thanks to the authors of the papers.

The Conference then adjourned.

On resuming the meeting on the third day—

Mr. A. P. I. Cotterell (the Chairman), introducing the papers that would be laid before the Conference for discussion that day, remarked that the papers of the previous day on " Activated Sludge " might have take much of the cream of the subject that they proposed to consider that day, but there was plenty of good rich milk left of which he hoped the delegates would not be slow to avail themselves. They proposed, in the first place, to consider several papers on sewerage or matters incidental thereto. Then, in the afternoon, it was their intention to deal with questions relating to sewage disposal in its widest sense, not the least important papers being a series contributed by representatives of several nations, dealing with the very important subject of the treatment of trade wastes.

He proposed to call for the first paper without further remarks except to say that to be engaged in the work of taking away that which was foul and impure from the abodes of men and of so treating it that it shall lose its foulness was no light honour. He gloried in the profession of a sanitary engineer. To make that which, once pure, had been sullied in its course, clean and sweet once more.

" As a soul that has sinned but is pardoned again," this is our goal : to make the river as in Kingsley's ode so that it may dare even to say,

" Play by me, bathe in me, Mother and Child."

SEWER PIPE WORK—ENGLISH PRACTICE.

By Edward Willis,

Engineer and Surveyor, Chiswick.

The title of this short paper is brief and elementary, but it occurred to the author that it might be useful to reproduce the principal pipe joints used in current English practice, and by discussion ascertain whether any improvements thereon had been adopted in other countries.

STONEWARE PIPES.

The earliest pipe work was executed with the old butt-jointed land drain, and many overflows of cesspools, sink drains, etc., were often connected thereto, and thence drained into ditches, streams and rivers.

The first improvement apparently was the socket and spigot pipe, the void between the two in the first instance being filled with clay.

The next advance on clay filling was a small section of gaskin, and the author has seen these joints still efficient after many years in use. On the other hand, when pipes were subjected to pressure internally by the sewer being surcharged, the clay allowed the water to penetrate, and thus a perfect joint was not effected under all conditions.

This ordinary socket joint was next filled with neat cement, or with neat cement and sand in the proportions of from 1 part of cement to 1, 2, 3 or 4 parts of sand. The object of the sand was mainly to avoid the risk of cement expansion, as on one occasion when opening a sewer the author found over 50 per cent. of the collars broken as the result of expansion, and this was so well known in the early days, that he has heard many of the older engineers in his young days oppose cement joints for this one reason. The addition of sand in varying proportions has lessened the risk of this trouble, and it was also used by some to reduce cost in view of the high cost of Portland cement.

Many engineers still use this type of joint, but, in practice, the author prefers a strip of tarred gaskin to be first caulked home, as this prevents the access of cement into the interior and also gives a truer joint.

The next advance, probably, on the original socketed joint was the Stanford bituminous joint. This had two main advantages :—

(1) That it gave a perfectly true line to the pipes, and a true invert ; and
(2) That it could be proceeded with much more rapidly, as the joints did not require any setting, but were efficient immediately after fixing.

In practice, the author has always used a bituminous joint where working below subsoil water level, or when reconstructing old sewers in cases where the flow has to be maintained the whole time during the progress of works along the same line of sewer.

There are many descriptions of bituminous joints, and a number of sketches are given showing the improvements or modifications of the original Stanford joint, but probably the best all-round joint of this class is a combination of the bituminous and cement, either by a double ring and liquid grout between same, such as the Hassall double-seal joint or joints of that type, or the single bituminous joint with a plastic cement filling in a longer collar outside of same.

About the time the Stanford joint came into prominence, the true-invert type of pipe joint was invented, and there are several varieties of these, which are indicated on the diagrams. Briefly, they consist either of a tapered spigot, as in the Knowles joint, or of a raised projection on the collar equivalent to the thickness of cement required to give a perfectly true invert. These joints are undoubtedly better than the ordinary socket joint, but, in practice, with a careful pipe layer the author has found a layer of gaskin properly caulked home gives a perfectly true invert without the faintest risk of the cement obtaining access to the interior of the pipe.

The screw bitumen joint has not come very much into prominence, although this was designed by Dr. Sykes, and at one time it was thought that it might take the lead in English practice.

It is now possible to get practically any pipe made by a manufacturer to suit the engineer's own design, providing ample time is allowed, but current practice is efficiently met by a single bitumen joint with a longer collar to take an additional cement filling.

It is, of course, needless to mention that Russian tallow or suitable grease should always be used when laying bitumen jointed pipes.

CONCRETE PIPES.

The joints for concrete pipes or tubes, as they are more often described, are of three types :—

(1) The rebated pipe ;
(2) The OG ; and
(3) The socketed, or double collar.

Illustrations are given of these joints, all of which the author has tried.

He is of the opinion that neither the OG nor the rebated joint is ideal for sewerage work in a gravel or sand soil, as such joints are most difficult to make and keep watertight. He has, therefore, used them considerably for surface water, but on no occasion for soil sewer work, this latter always being laid with socket or double collar joint.

He has, however, adopted the concrete tube, both reinforced and otherwise, with considerable success. He finds the collar joint, sometimes fixed in the form of a socket, can be made efficiently watertight, and he has also used the spun concrete tubes reinforced on the Stanton Hume process, having laid several thousand feet of 3 feet diameter purpose-made pipe in 8 feet lengths.

Whilst dealing with concrete tubes, one should mention the cast iron concrete lined pipe, which should be of great utility where the water in the sewage is found to act upon the iron. There is no serious difficulty in the jointing, as it would be dealt with by gaskin and molten lead or gaskin and lead wool.

IRON PIPES.

The current practice in iron pipes for general work is the ordinary beaded spigot and socket, but for good class work and pumping mains, the turned and bored joints in steel or iron are more often used.

It is also necessary to refer to the spun iron pipes which give considerable extra strength, but the author has had no experience of the use of these pipes for sewerage work. He would, however, have little hesitation in using same should occasion arise.

The ordinary screwed collar joint is seldom used for permanent sewerage work, although the author has adopted same for temporary purposes during minor repairs or relays. This, as illustrated, is so well known that no comment is necessary.

WROUGHT STEEL PIPES.

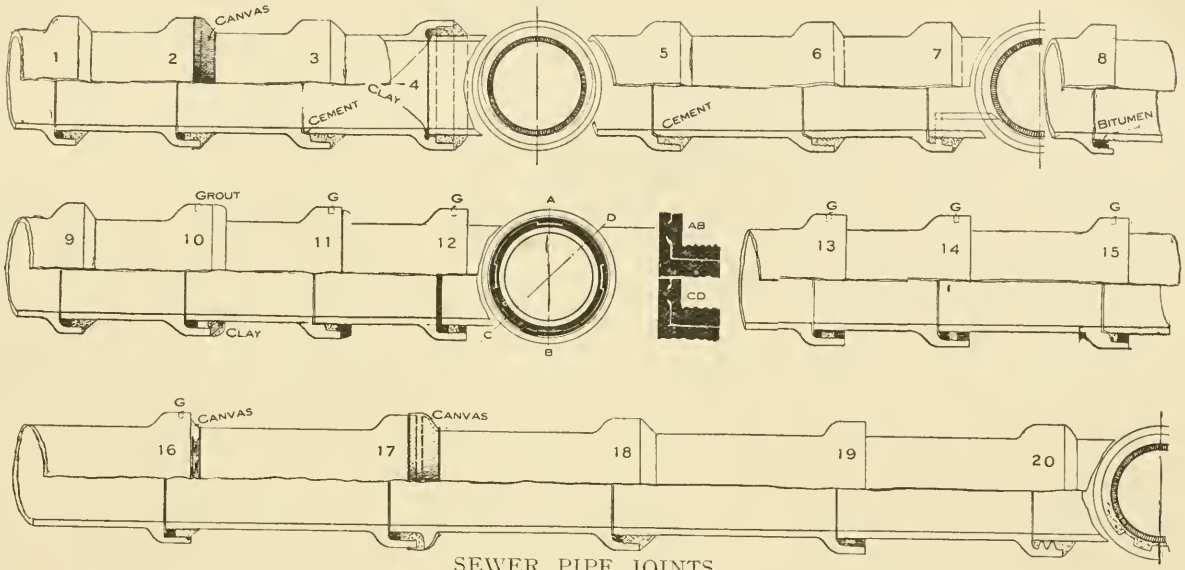
There are two kinds, the welded and the riveted, but current practice does not usually adopt such pipes except in crossing bridges or for syphons under bridges, canals, etc., and for sea and river outfalls.

The author cannot speak from personal experience as to the relative advantages of these steel tubes, but he believes that both would be equally efficient if properly protected from the corrosive action of sea water or abnormal trade refuse.

In view of the extensive use of drawn steel tubes for water supply, it would seem that possibly in the future these tubes might take a more prominent place in English sewer pipe practice, where subject to slight settlement, but protection from electrolysis would be necessary.

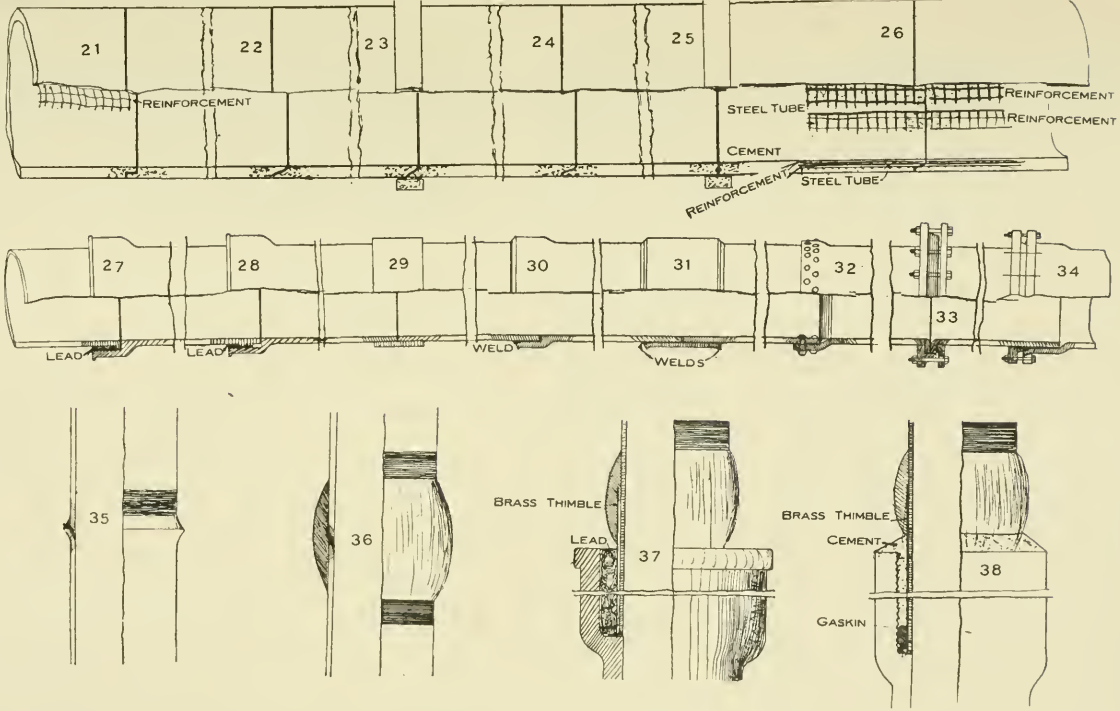
FLANGED JOINTS.

Flanged joints are still used in connection with sewerage work, more particularly on pumping or suction mains, and, if possible, the joints should not only be turned to a true face, but should also have the joint



SEWER PIPE JOINTS.

1. Common Joint. Two thicknesses of Gaskin well caulked. Joint of Cement and Sand (1 to 1). 2. Common Grouted Joint with temporary Canvas band. 3. Knowles' "Free-Flow" Pipe Self-Inverting owing to Patent Tapered Spigot Joint made first with Plastic Cement round Spigot and finished with Portland Cement as No. 1. 4. Ewings' "Xcentric" Joint Self-Inverting by Eccentric Shoulder on Socket. Joint with Portland Cement. 5. Suttons' "Concentric" Pipe similar to No. 3. 6. Doultons' Self-Centreing Joint similar to Nos. 3 and 5. 7. Doultons' "Level-Invert Joint has supporting Shoulder Piece extending ⅓ round Socket, thus supporting Spigot. 8. Stanford Joint consists of two Bitumen Rings only, formed in Ball and Socket manner. This Joint may be finished with Cement if necessary. 9. Hassalls' "Single-Lined" Joint. 10. Hassalls' Single-Lined Joint Deep Socket. 11. Archers' "Xcentric" Joint. 12. Suttons' Flush-Joint Pipe. This Joint may also be obtained without the second ring of Bitumen on Socket and Spigot. 13. Plain Double Grout Joint. 14. Hassalls' "Double-Lined" Joint. 15. Suttons' Concentric Double Seal. 16. Ring Grout Joint. 17. Doultons' Grouted Composite Joint. 18. Tyndale Joint. 19. Oakes' "Oanco" Joint. 20. Albion True Invert Pipe.



SEWER PIPE JOINTS.

21. Plain Rebated Joint. Note Cruciform Reinforcement of Pipe. 22. Plain OG Joint. 23. Socketted or Double Collar OG Joint. 24. Stanton Hume Patent OG Joint (without Collar) Depth of Recess=Thickness of Pipe. 25. Stanton Hume Collar Joint. Note recess for Elastic Cement. 26. "Ponna" Pipe. Note Sheet Steel Tube and Cruciform Steel Bar Reinforcement on both sides of it. 27. Beaded Spigot Lead Wool or Molten Lead Caulked up tight. 28. Turned and Bored Lead and Salammoniac Joint. 29. Screw Joint. 30. Stewarts' Welded Joint. 31. Stewarts' Loose Collar Welded. 32. Lap-Riveted. 33. Stewarts' Loose Flanged Joint. 34. Drees Joint (Allows for Expansion). 35. Copper Bit Joint (Bad for any vertical drainage work). 36. Wiped Lead Joint. 37. Lead Pipe Joined to Cast Iron. 38. Lead Pipe joined to Stoneware.

packed with thin suitable asbestos millboard, although the author believes some engineers prefer metal to metal contact.

The British standard flanged joints, as recommended by the British Engineering Standards Committee, are probably the best to adopt in all cases.

LEAD PIPES.

Whilst it is seldom a lead pipe sewer is adopted in English practice, in fact, the author is not aware of any lead underground pipe sewer, yet it is the current practice for vertical pipe work in England to be constructed in this material and in some cases where the closets or slop sinks from adjoining houses discharge into the same soil pipe, such pipe becomes a sewer under the Public Health Act definition.

There are only two recognised joints, viz. :—

(*a*) The copper bit joint, which should never be used, as it has but little strength ; and

(*b*) The properly wiped joint, which is the standard practice.

It must, however, not be forgotten that lead and cement do not work satisfactorily together, and, therefore, the connection of lead to stoneware or iron should be made by a copper or brass collar, which is first wiped to the lead pipe and then is subsequently made good to the iron pipe by molten lead or lead wool, or to the stoneware pipe by a cement joint.

DISCUSSION.

Professor E. R. MATTHEWS (Head of the Sanitary Department, H.M. Office of Works), whom Mr. Willis, in his absence, had requested to represent him, referred to a number of points not dealt with in the paper, though, he said, the paper was very concise, and contained a good deal of information. There was no mention, however, of the methods of constructing sewers of large section in this country, because the paper was confined, as the title indicated, to "pipe work." In the United States they carried out a lot of reinforced concrete conduit and aqueduct construction, and it had fallen to his lot to do a good deal. He considered that, for sewers of large section, there was no method of construction which could in any way compare with that of reinforced concrete. Unfortunately, engineers in this country were inclined to be conservative, and did not like to take on anything new. It was not sufficient for them to know that some other country had done this, and they looked with suspicion on any new method if it did not coincide with their ideas. Therefore, the usual method of construction of large sewers in this country —sewers large enough for a man to walk through—was in brickwork, on a concrete foundation, and backed with concrete. Dealing with the intercepting trap, for stoneware pipes, he referred to papers which were to be read on the following day, under the heading of Plumbing and House Drainage. One of the authors (p. 257) had very strongly condemned the intercepting trap, and had accused the English of being conservative. He (Mr. Matthews) agreed, to a large extent, that under certain conditions it should be abolished. He himself was carrying out drainage schemes for H.M. Office of Works all over the country, and he had abolished the intercepting trap in many cases. For the benefit of overseas delegates, Mr. Matthews explained the functions of H.M. Office of Works. This Government department was responsible for the maintenance of all Government buildings and official residences at home and abroad ; this included the Houses of Parliament, Buckingham Palace, St. James's Palace—in fact, anything from a small Post Office to Buckingham Palace was dealt with by this department, both for new works, and the maintenance of existing works. The department had also been dealing with housing schemes all over the country. In that connection he had divided the houses into groups, and in some cases he had allowed sixteen houses which were draining into one sewer, to have one intercepting trap. In another case, he had allowed the drainage from eight houses to be brought into the same manhole, and to pass through one interceptor. In cases where he thought a trap was unnecessary he had abolished it altogether. As to the jointing of stoneware pipes, he agreed with Mr. Willis that the use of a strip of tarred gaskin, caulked home, with an ordinary socket joint filled with cement, made a good job. He (Mr. Matthews) said he laid his pipe sewers on a bed of concrete, and usually haunched them with concrete. When the pipes were to be laid under a building they were surrounded with concrete if sanitary pipes, the alternative method being to put in iron pipes. He advocated this

method strongly. The cost of iron pipes had been reduced to such an extent that in three out of four schemes he had designed for re-draining big buildings he had put in all iron pipes. Concrete tubes had not been mentioned by Mr. Willis, but whenever he (Mr. Matthews) was putting in a sewer with a diameter greater than 18 inches, he put in concrete tubes. If they were to be laid deep, they were reinforced, but if they were to be laid to a shallow depth and there was no weight likely to pass over them, he did not have them reinforced.

Mr. W. J. Oakley speaking of the difference between earthenware and iron pipes, from the medical point of view, said that in his opinion earthenware pipes tended to carry disease rather more than did iron pipes, because they were so very difficult to get at should there be a stoppage, whereas, with iron, it was just a question of uncovering, taking the old pipe out, and putting a new one in, which was much easier.

Mr. T. Chalkley Hatton (Milwaukee, U.S.A.), dealing with joints, said that he had tried all the bitumen and many other types of joints, that he knew of, but had abandoned them all after a good many years of trial, and had come back to the cement joints, with caulked gaskins first, then cement sufficient to fill the joint thoroughly, after which the outside of the joint is covered with cloth so as to prevent the cement from being washed away from the joint in very wet work. He had found that this type was the best joint that could possibly be made, whether it was in wet or dry trenches. The question of the small concrete pipe has been a matter for a great deal of discussion in the States for a good many years. There was an association of cement manufacturers, which had propagated the idea of using the cement pipe instead of terra-cotta. In carrying out work in Milwaukee recently he had built about thirty-five miles of deep intercepting sewers, during which he had encountered a good many pipe sewers and had to interfere with them. At least 60 per cent. of the concrete pipes, which had been laid for many years, were broken. Some were destroyed by erosion, or disintegration and 60 per cent. of them at least were cracked either longitudinally or circumferentially. The trouble with concrete pipes was the difficulty of inspection. Inspectors could examine the stability of a terra-cotta pipe by a field test very quickly, but they could not do that with a concrete pipe. Concrete pipes were frequently received uncured, and he had found that unless he could put an inspector in the concrete pipe manufacturer's works, to inspect every point in the process of manufacture, he could not be sure as to how a particular concrete pipe was made. Therefore, he had abandoned the use of concrete pipes, at least in cases where the pipes were more than 6 inches in diameter, unless he could have them inspected thoroughly, and the manufacturer or the contractor paid for the inspection. Even then he laid concrete pipes in concrete cradles. In the work he had been doing in Milwaukee, where he had laid sewers of 24 inches in diameter or less, in the intercepting sewers, he had had terra-cotta pipes

embedded in a full envelope of concrete. He believed that was economical, and the furnishing of the concrete envelope was a very small portion of the total expense. Therefore, why not add that small portion of expense, and make a sewer which one knew would last as long as it would be needed? One could not expect a terra-cotta pipe to last so long without the concrete envelope. Another advantage in laying a pipe with a concrete envelope was that you were sure of getting an absolutely good flow line. With regard to concrete conduits, in the U.S.A. they were laying them almost exclusively, probably for economical reasons. Throughout the U.S.A. there was a very strong bricklayers' union. Bricklayers were rather expensive; they received $1.25 per hour, especially sewer bricklayers; and the union rules limited the number of bricks they could lay per day. Therefore, most engineers who had to lay sewer conduits larger than 24 or 38 inches in diameter used concrete almost entirely, because they could lay them with unskilled labour, and at very much less cost than they could the brick conduits. Again, it had been found that in many instances the mortar forming the joints of the brickwork disintegrated, and, while it only disintegrated at the surface of the joints, it resulted in a very rough surface, and a high coefficient of friction, which reduced the flow.

Professor MATTHEWS, replying to a question by Mr. Fuller, said he had never used the Hassall patent joint, and, in the many miles of pipe sewer he had put in, he had only used a patent joint on one occasion. In reply to Mr. Oakley, Mr. Matthews said he did not think the question of health came in at all, if the material of which the pipe was made was properly glazed. Iron pipes could be inspected just as easily as earthenware pipes, if the inspection facilities were provided in the right positions. He was very interested in Mr. Chalkley Hatton's experience, and asked if he had any means of checking the cement used in the manufacture of concrete pipes.

Mr. CHALKLEY HATTON replied that this could be checked by the inspector at the manufacturer's works.

Professor MATTHEWS asked if engineers had power to say to the manufacturers, "You are supplying us with 100 pipes, and we shall come to your works and see the materials they are made of."

Mr. CHALKLEY HATTON said they required that now.

Professor MATTHEWS, referring to the envelope mentioned, in which the pipes were embedded, asked what shape it was, and whether its purpose was to support the two ends of the pipes.

Mr. CHALKLEY HATTON replied that the concrete envelope was in the form of a cradle, 4 inches wider than the pipe, in which the pipe was laid.

The cradle was made first in some instances to a level corresponding to the spring line of the pipe ; in others the pipe was first laid to line and grade, bored in on concrete blocks and the concrete cradle then laid around the bottom and up to the spring line. Usually this concrete cradle was built so as to fill the trench to its sides.

Mr. W. H. MAKEPEACE (Stoke-on-Trent), commenting on Mr. Matthew's reference to the reluctance of the English engineer to use reinforced concrete for large size sewers, said there were good grounds for not using it, particularly in districts which were very seriously affected by mining subsidence. He came from a district where one of the principal industries was mining. Three or four years ago they were considering the question of designing a main outfall sewer, about four or five miles in length. Before deciding they had made a careful inspection, in order to ascertain their condition, of the existing brick culverts or outfall sewers which had been used for fifty years or longer, and which had passed through areas seriously affected by mining subsidence ; as a result, they had come to the conclusion that, owing to the elasticity of the brick culverts, and the fact that they were more readily accessible, and more easily repaired, than reinforced concrete tubes, there was a good deal to be said for a properly laid brick culvert, in such a district. He mentioned this as one of the reasons why engineers in this country hesitated to use reinforced concrete for outfall sewers. With regard to smaller work, nearly every stoneware sewer laid to-day in this country was either supported on a concrete foundation or entirely embedded in concrete, because it was considered that, having gone to the trouble and expense of excavation, it was worth while to go to a little extra expense to protect the sewer from outside influences. With regard to wrought iron and steel, he had inspected some wrought steel tubes put down during the war, and had found that the corrosion internally, on the upper part of the tubes, owing to the condensation of the sewage, was so great that he was satisfied that in another two or three years they would be useless. Flanged pipes were not used much in this country, because they had not sufficient elasticity to enable them to cope with subsidence.

Professor MATTHEWS said his experience coincided with that of Mr. Makepeace on most of the points he had raised. In constructing sea outfalls he purposely avoided anything like steel tubes, because rust accumulated almost before the tubes were laid. He had used wrought iron pipes supported on pitch pine piles, but had found that the wrought iron bolts began to rust away in about six weeks. At every joint where a flange occurred there were holes, where the wrought iron had suffered from erosion. His practice now, for sea outfalls, was to put in ordinary spigot and socket pipes, with no bolts at all, but with just lead joints. They seemed to hold up all right.

Mr. COTTERELL (the Chairman) asked Mr. Chalkley Hatton if, in the States, they used, in place of gaskins, a method which had been used

occasionally in England, namely, cement sausage bags tucked into the joints of the stoneware pipe.

Mr. Chalkley Hatton said they had used it very frequently in the States, especially for wet work.

Mr. Cotterell (the Chairman) said he believed the Victaulic joint—which was a removable socket—was coming into use in this country, and asked if that were so in the States.

Mr. Chalkley Hatton said he did not know the joint by that name.

SEWERAGE IN LOW COUNTRIES.

By B. A. Verhey,

President of the Dutch Society of Consulting Engineers.

Read by Mr. C. G. Klaarhamer.

INTRODUCTION.

It may be supposed to be known, that a great portion of the Netherlands is at a low level, partly under sea-level and partly under the water-level of the rivers. Also the canals of the west portion of the Netherlands are as a rule at a higher level than the adjacent land, the difference in level being in some cases more than 5 metres.

The drainage of these low lands, which are divided up in "polders," consequently cannot occur by a free outlet, but has to be done by means of pumps. To this effect the lands are intersected by ditches, in which the water-level is kept 0.20 metre to 1 metre under the surface of the land, considering the nature of the crops and that of the earth.

Plough-land requires a lower water-level than grass-land, whereas bogpeat does not allow a too intense drainage. If this latter is done the porous peaty ground will shrink, by which the level of the ground will sink.

Lowering of the water-level will be followed immediately by subsidence of the peaty ground surface.

History can explain why the west portion of the Netherlands is the most densely populated, in spite of its situation, which is unsuitable for town building.

Trade and navigation caused the population to settle in the west of the country and along the borders of the large rivers, in earlier days even risking inundations over and over again.

This danger is now taken away, as the rivers are gradually altered, so as to get rid of water and ice: on the other hand the dikes are so constructed as to resist the pressure of high water.

There still exist technical and financial difficulties to overcome for obtaining satisfactory hygienic conditions in this country.

RELATION BETWEEN TOWN-PLANNING, SEWERAGE AND SEWAGE DISPOSAL.

We take it, that by the total absence of appreciation of æsthetics amongst former generations of engineers, the architects have made themselves its true representatives for public works.

Without much opposition they have claimed all the work connected with town-planning as their own, although they were certainly not superior to the engineers in matters of highways and road requirements and technics.

Consequently town-planning is looked upon more as a question of pure æsthetics, whereas other considerations did not sufficiently count.

The increasing traffic, which was even evident to the man in the street, forced them, to draw the problems of road requirements within the circle of their activities. As a rule they forgot to study the question of sewerage, when making their plans.

The main sewers situated at the greatest depth under street-level must be laid in broad, wide streets ; consequently it will be becessary to fix the direction of the main sewers, during the making of plans for a town-extension. The position of the main sewers will be further influenced by the choice of the most favourable spot for the main drainage outlet or for the sewage disposal plant.

The future level of the streets will be influenced very much by the sewerage system.

In the " polders " it is the custom to raise the surface of the building ground. Two results may be obtained by that. In the first place the surface may be raised so much that a free outlet from the sewers into public water can be obtained ; in the second place the surface may be raised only so much that the sewers are situated above the ground water-level.

In the first instance the costs of a pumping station are avoided, in the second instance a pumping plant will be necessary but percolation of the ground water into the sewers will be prevented.

Although various steps are to be taken to diminish as much as possible the quantity of ground water, penetrating into the sewers, nevertheless there will be always a certain quantity finding its way into the sewers, if by means of pumps the water-level inside the sewers is made lower than that of the ground water.

In that case the sewerage system is at the same time acting as a drainage system of the ground.

The latter is not advisable as it causes an increase of the exploitation-costs of the pumping installation, and as the lowering of the ground water-level may be dangerous for the wooden piling on which the foundation of buildings is laid.

So at Rotterdam expensive repairs were found necessary for a number of buildings, owing to the lowering of the ground water-level, caused by the draining action of the sewers.

In each case it will be necessary with a view upon the cost of exploitation to decide how the drainage of the town-extension must be planned.

Raising of the ground level by bringing up sand, will be preferred from hygienic considerations, especially to obtain a sufficient difference between the surface of the ground and the ground water-level.

This difference must be about 0.80 metre ; at the same time a solid covering of the original ground is obtained, if this is of a peaty character.

Still in another way the town-extension is influenced by the sewerage requirements. In each sewerage system storm water outlets are made, so that an excess of rain-water can be let out. These outfalls are located as much as possible throughout the whole system, so as to keep the section of the sewers as small as possible.

In case the water, coming from the stormwater outlets cannot fall into the public water owing to the higher level of the latter, and in case of the absence of public water, it will be necessary, especially for extensive plans to dig ponds or ditches, which at the same time fit in the extension-plan and in the sewerage-plan.

As far as this water, which is stored up in ponds and ditches does not disappear into the surrounding ground or does not evaporate, the water-level must be kept normal by pumping. For greater ponds a windmill may be used economically for pump driving.

GROUNDS WITH HIGH GROUND WATER-LEVEL.

These are grounds with a ground water-level from 0.20 metre to 1.50 metre under the ground-surface.

a. GROUNDS SITUATED ABOVE HIGHEST RIVER- OR CANAL-LEVEL.

Supposing the grounds are at a sufficient height above the level of the public water, then the sewers have a free outlet. Those towns in the Netherlands which are situated on high grounds along the river are in this favourable position, but even in this case the grounds close to the river are hardly above the highest level of the river. As the outfall of the sewers must be kept as much as possible under the lowest water-level, it will be imperative to keep the excavations for the sewers dry during the preparation, by means of pumps. This latter is not always an easy job.

Supposing the town to be drained is situated on the slope of a hill, which consists in the Netherlands of sand, then the rain-water will penetrate into this sand, and will cause a ground-water current in the direction of the river, which will rise and sink with the level of the river.

Very often it will be impossible to carry out these extensive works during the lowest river-level and in that case the sewers are laid in strata of sand or gravel, often several metres under ground water-level.

b. GROUNDS SITUATED UNDER RIVER- OR CANAL-LEVEL.

In this case one has the choice between raising of the surface so that the sewers have a free outlet, and a pumping scheme.

Raising of the polder fields, situated along the large rivers above the highest level of the river water is most times uneconomical owing to their low position. As a rule broad meadows are situated between the dikes and the summer-bed of the river, called " uiterwaarden " usually

protected by lower dikes, which are inundated during high floods. These "uiterwaarden" are mostly situated considerably higher than the surface of the polders inside the dikes; consequently some municipalities have to consider the question either to extend the town on land outside the dikes, which land in that case has to be raised above highest river water-level, or to plan out the extension inside the dikes, but then under application of a pumping scheme.

This question can be solved after comparing the estimates for both plans. Nevertheless under circumstances the government do not allow to raise the surface of the "uiterwaarden" as it hampers the flow of the water during higher levels, diminishing the capacity of the bed of the river. Industrial and commercial districts, which as a rule are situated along the river side have to be built above the highest river water-level.

There are, however, different questions to be solved, connected with town-extension inside the dikes.

Making the outfall of the sewerage system into the polder-water, which has the same level as the ground-water, has technical possibilities. This, however, is often forbidden in the by-laws of the polders for comparatively large quantities of untreated sewage into the mostly small ditches, whereas the outfall of untreated sewage into the rivers is allowed, there being no law preventing the pollution of public waters.

One has to choose between two possibilities:

a. The outlet into a river, without treatment and in that case pumping will be required.

b. Treatment of the sewage before letting it out into the polder, taking into consideration the following points:

1. Raising to such an extent that a pumping plant is unnecessary,
2. No raising at all,
3. Partial raising.

Raising to such an extent that a pumping plant is unnecessary, will seldom lead to an economical solution, and specially not so in those polders where the soil is peaty, and considerable sinking of the original soil will be caused by the raising with sand.

Moreover there are several difficulties in building upon such raised land. During the first years after the raising the new layer of sand will sink continuously in the original subsoil, whereas the sand layer itself will shrink, so that building without piling is dangerous in the early years.

However, building over a foundation on piles is very expensive; to prevent the wooden piles from rotting, these have to remain under the ground water-level, for which deep excavations may be necessary, whereas practice has proved, that during a further sinking of the subsoil, the layer of sand causes considerable friction against the piles, which works as an extra load, so that more piles are necessary. The deep excavation can be avoided by using piles, made of concrete, which as a rule are considerably more expensive than wooden piles; it is also possible to lengthen the wooden piles by a wooden or concrete lengthening-piece.

Most times a choice must be made between no raising or partial raising. In plans of some considerable extension without raising of the field, the sewerage system must have a very deep position, so as to get the necessary fall. The estimates of the costs have now to prove which system is the more economical, either with the deep situation of the sewerage system, without raising of the ground, or a partial raising, for which the raising by sand has to be paid, but on the other hand the expenses for deepening the sewerage system are much lower.

So as to avoid a too deep laying of the main sewers, auxiliary pumping plants may be applied for lifting sewage from one section of the sewers to the next.

Especially in weak and in sandy soils deep excavations under ground water-level cause high expenses, due to expensive timbering, as the sides of these excavations must be kept in position by bulkheads, and moreover these excavations must be kept dry at high cost, especially if bore-wells must be arranged.

The outlet into the polder, connected with the treatment of the sewage, has the advantage, that the installation for the treatment can be built in such a central position, that the length of the main sewers and consequently the deep position can be limited. The same advantage can be obtained by a pumping installation, delivering its contents into the river.

This pumping installation can be planned in the same favourable position as the installation for sewage treatment ; but it stands to reason that the delivery piping from the pumping installation into the river must be longer, than if the plant could be arranged close to the river dike.

From the above it is to be seen, that to come to an economical arrangement, consideration must be given to various difficult points, and that there is a close relation between town-planning, sewerage system, and sewage treatment.

CONSTRUCTION.

During the carrying out of sewerage works few difficulties are experienced. The proper fitting of the joints between the sewer pipes requires careful handling but does not cause difficulties.

The real trouble begins during excavation in weak soil under ground water-level.

Although expensive it will sometimes be advisable to make a foundation of piles underneath the sewers, preventing subsidences and consequent leakage of the ground-water into the sewers, and eventual overloading of the pumping scheme.

The subsidence of the sewers will be followed by a draining of the subsoil, which will cause lowering of the ground water-level and consequently rotting away of the top of the wooden piles.

In the end the sewers have subsided so much, that they fail to function properly and a new sewer must be laid.

There are towns in Holland where there are three sewers one above the other, owing to this reason. In case the subsoil consists of sand

and the work has to be executed under the ground water-level, a mere sinking of the end of the suction pipe will not be sufficient and bore-welling must be applied.

By this latter the ground water-level will be lowered, and the job can be carried out in a perfectly dry excavation, which never will be the case if ordinary pumping is done. The cost of bore-welling is pretty expensive but by facilitating the carrying out of the work, it is more economical in the end.

MATERIALS.

In Holland the sewers are nearly always made of concrete not reinforced of which the section is circular or egg-shaped and in lengths of 1 metre. The measurements, as well as the testing requirements, are standardised.

For small diameters stoneware pipes are used, whereas in special cases reinforced concrete sewers are applied.

Up to the present time no serious objection was found to the sewers being made of Portland cement concrete. The exterior was not attacked in peaty soil, neither the interior by sewage.

Only one case is known at Amsterdam where the surface of the concrete was affected by the peaty ground water. By addition of trass to the concrete no further effects were experienced. Yet it might be possible that these pipes are not suitable for the waste water from certain factories.

The best guarantee will be a sufficiently large proportion of Portland cement, and first ample time must be given to the process of curing by atmosphere after construction before the pipes are exposed to damaging fluids. The stoneware pipes are standardised as well as some further parts of the sewerage system.

PUMPING STATIONS.

These have reached a high degree of perfection. Specially by the introduction of electromotors it became possible to make the pumping stations fully automatic.

Centrifugal pumps of special construction are applied as a rule for these purposes. Very little is to be said if these pumps are driven by steam engines or by internal combustion engines.

With electrical driving, automatic arrangements are possible and already of such a perfection that more and more pumping installations for sewerage systems or for polders are made automatic.

As a rule centrifugal pumps for sewage must always be kept full of water in case of automatic action. A vacuum pump may be applied for this purpose, brought into action by a floating switch after which another automatic arrangement will start the sewage pumps. This method however is objectionable owing to the many automatic arrangements.

Therefore it is preferable to have the centrifugal pumps placed under the lowest level of the sewage. Such a location of the pump is possible

in different ways. First by placing pump and motor combined in one water-tight pit under lowest sewage level.

The pump sucks from an adjacent underground reservoir, in which the sewerage system has its main outlet. By means of a float and controller, connected therewith, the pump is started if sewage reaches a maximum level and is stopped at a minimum level.

Such a pit must be well-ventilated but even then the air inside is too damp for the switches and controllers and consequently these must be placed in a small building over the pit.

Often the motor too is fixed in this small building and in that case pumps and motors must be of the vertical type. Many of these arrangements are already carried out in Holland.

Vertical pumps allow for one further step to do away altogether with the water-tight pit. The pump is then placed on a set of girders under lowest sewage level in the underground reservoir, referred to above. This saves the cost of water-tight pits, but eventual repairs to the pump are less handy.

These automatic pumping installations promise many possibilities when planning out sewerage systems.

As the pumping installation is inexpensive and the size of the pumps allow for small building accommodation, we expect that by the system just described, by which it is possible to have the sewers located at a much smaller depth in the ground, thus saving large expenses for laying them deeper, pumping will sooner be applied than in earlier times.

DISCUSSION.

Mr. HARRISON P. EDDY (Boston, Mass, U.S.A.) referred to the statement made in the paper (p. 169) under the sub-heading "Materials," which read :—" Up to the present time no serious objection was found to the sewers being made of Portland cement concrete. The exterior was not attacked in peaty soil, neither the interior by sewage." It might be of interest to know of some experiences with Portland cement concrete pipes in the States. A number of years ago he had laid a great many under-drains of Portland cement concrete pipes in intermittent sewage filter beds built of sand. This was at Worcester, Mass., an industrial city, where a considerable quantity of acid pickling liquors were discharged into the municipal sewers. The pipes were laid practically at the natural ground water-level, so that the filtered sewage passed down through the sand to the natural ground water-level and then out through the pipes. Furthermore, some of the beds were constructed upon a stratum of peat. Trenches for the drains were excavated to hard ground, and the pipes were surrounded with sand. There was opportunity for the peaty soil to communicate its extractive properties to the natural ground-water. Further, the filter beds were dosed so heavily that at times they became putrid. The sand at the bottom became black, with sulphide of iron, and the blackness worked towards the top, so that, from time to time, it was necessary to cut out the beds, and allow them to rest and oxidise, to get rid of the black sulphide of iron. After a very short time it was found that the concrete tubes were seriously attacked, particularly on the outside, but only slightly on the inside. In many cases the action was so severe that the pipes were actually perforated. There were three possible causes of this, and perhaps more. In the first place, the pipes were laid in peaty ground, and there was possibility of action by organic acids. That, however, seemed rather improbable. In the second place, at times, there was acid in the sewage, although much of the time it was alkaline. He received the alkaline waste from industries, but there were times, undoubtedly, when the sewage was very slightly acid. But the major quantity of the effluent passed out through the inside of the pipes, which was not much attacked, so that it would seem, perhaps, that this possible cause was only of secondary importance. The third possible cause, which seemed to be the most important of the three, was the fact that the pipes lay in ground-water, which, at times, was in a septic condition, and that the changes in the chemical compounds resulted in the formation of a sulphur acid which actually attacked the cement. That experience, of course, was an extreme case. In general, many sewers in the States were laid in or near the ground water-level, and comparatively few sewers, as expected, were sewage-tight or water-tight; at times, the ground-water, probably leaked into the sewers, but at other times the sewage escaped into the ground, and might not this sewage create a condition similar to the one he had described as having existed under the filter beds? If so, that might well account for the action on some of the cement concrete sewers in public streets. There was an intense warfare going on

in the States between the cement concrete pipe industry and the clay pipe industry. The cement industry had no doubt, by reason of competition, caused much improvement in vitrified clay products. The difference in price, generally, between the cement concrete pipe and the vitrified clay pipe was very slight, and, when one considered the life of the sewer in relation to the cost of the material used and the other items of cost of a sewer, it was a question to be considered whether it was wise to use the concrete pipe in the small sizes. In large sizes they had used concrete very extensively, and, perhaps, they were somewhat irrational in questioning the use of concrete for smaller sizes and yet adopting it in the large sizes. In the large sizes, however, the sewer had thick walls so that chemical action, to the destructive point, would be correspondingly delayed.

Mr. Arthur J. Martin (Past President, Institution of Sanitary Engineers) said that "Trass" was a material—a silicious earth—which was found in connection with volcanic deposits in Italy, where it was known by the name of "Pozzuolana." It was mixed with lime to form a hydraulic cement. He had had little experience of concrete pipes in small sizes, but he had been struck with the extent to which such pipes were used both in North and South America, where it was a matter of difficulty to get stoneware pipes at anything like a reasonable cost, owing to the great distances they had to be conveyed. It was not merely a matter of the cost of the pipes and the cost of carriage, however, for the question of breakage also came in, and he had found a strong tendency to use concrete pipes in those countries. He was at present dealing with a case in South America where stoneware pipes were considered prohibitive in point of price, and where, moreover, there was practically no material available for concrete of the ordinary kind. They proposed, therefore, to use cement, with sand—a selected sand, as coarse as possible—in lieu of the ordinary aggregate. He would have been glad to hear from the author on the subject of gradients. Sanitary engineers in this country were brought up on textbooks which prescribed gradients and velocities which were seldom obtainable in practice. There was, probably, not a town in the country where they did not find a number of sewers in which the velocities were far less than what was regarded as the lowest self-cleansing velocity. It was true that, on paper, the gradient gave a velocity of 2, 2½ or 3 feet per second, but if they took into consideration the quantity flowing they would find that the actual velocity was only 9 or 10 inches per second. He had had recently to report on a number of sewerage schemes, in one of which he found an 18-inch pipe at a gradient of 1 in 750, to take the sewage of thirty houses; the velocity would be about 6¾ inches per second. So that, although we professed certain things with great fervour, we did not always live up to our professions.

Many years ago he had reported on the sewerage at Middleburg, not far from Flushing, in Holland. The whole place was at or about tide level.

Mr. C. G. KLAARHAMER said the sewers were connected with the large canal there. The tide is absolutely always level.

Mr. MARTIN, continuing, said that in Holland it was probably the exception to find a city or town in which it was physically possible to lay sewers at the gradients we were accustomed to call for in this country. He believed there were many places where the sewers were laid almost flat, and where for cleansing purposes they relied upon the tide—where there was a range of tide. He would like to ask Mr. Klaarhamer whether it was not the fact that in Holland sewers often had to be laid almost without regard to gradient, but, by taking advantage of flushing from the sea or from the canals, they were able to keep the sewers respectably clean. He had a case of that kind to deal with where the best gradients obtainable were exceedingly flat, but where, by taking advantage of the rise and fall of the tide, he was able to get a self-cleansing system.

Mr. CHARLES SHARP (Dorset) said that 1924 was the fiftieth year in which his firm had been making concrete tubes, and they had introduced them from America. He recollected that their earliest testimonials to the suitability of concrete for sewers were those of American city engineers, and one of them stated that concrete sewers had been in use in the city of New Bedford, Mass., since 1846. He did not know whether the chemical conditions in the soil in America were different from those in this country, but, with reference to peaty soils, we were not without them in England, and yet he knew of no case of concrete tubes being attacked by peaty subsoil water. But he had always been inclined to think that we in England had maintained our pre-eminence in the manufacture of Portland cement, and that the quality of Portland cement obtainable in this country was so exceedingly high that concrete tubes made from it would stand where tubes made of lower quality cement would possibly perish, because there was an enormous variation in the quality of Portland cements. His firm manufactured stoneware as well as concrete pipes—an unusual combination, but they had started to make concrete pipes in order to make bigger pipes. Although very large stoneware pipes were sometimes made, the question of cost always came in, and undoubtedly large size units—say, of 18 inches diameter and over—could be made more economically in concrete than in stoneware. The converse also hold good, i.e., the small units of stoneware could be made far more economically than small units of concrete. That, he believed, was a fundamental fact, and whether they were talking of building houses with concrete blocks instead of clay bricks, or anything else, that distinction between clay and concrete would always hold good. With regard to durability of concrete, he had read of the war between the clay and concrete industries in the States, and there had been a certain endeavour made to introduce it into this country, but the simple fact remained that, although there were all sorts of reports of the failure of concrete pipes in America, they would not carry conviction in this country,

because corresponding reports of failures of concrete pipes in England could not be found. Consequently, the makers of clay pipes had felt—they had been very prudent—that if that sort of contention were started, here the makers of concrete pipes would be able to show at least twenty failures of clay pipes to every single one of concrete. Possibly that was why we in this country had not heard much of that contest. Portland cement could only be attacked by strong acids, and, where there were exceptional cases of strong trade wastes going into the sewers, caution should be observed. On the other hand, he believed that in these days no manufacturer making use of chemical products would be so extravagant as to allow strong acids to run to waste into the sewers. He would recover them for their commercial value, and consequently, the question of trade wastes being of sufficient strength to injure a well-made concrete pipe was not worthy of consideration in practice. Sixty years or more ago, Mr. John Grant, the first Engineer to the old Metropolitan Board of Works, constructed in London miles of huge sewers in concrete, which, presumably, are working efficiently to-day, and the mass-concrete of those days could not approach in quality the concrete used to-day for pre-cast concrete tubes.

Mr. Willis, in his paper, had referred to OG joints as not being altogether good, in a gravel or sand soil, but it should be borne in mind that large size sewers, of 15 inches and upwards, whether of stoneware or concrete, as pointed out by a previous speaker, were almost invariably laid on concrete, and to go to the expense of deep excavations and then not put in a well-founded sewer was not wise. Therefore, if a pipe were to be embedded in concrete and haunched up half way, there was no difficulty in putting a fillet of cement mortar round the joint and getting as tight a joint as with a socketed pipe.

Mr. F. C. Temple (Jamshedpur, India) supported the claim made in Mr. Verhey's paper that the drainage engineer should have a say in the lay-out of the town. Whenever there was an opportunity of extending an area, there was a good deal to be said for laying out the lines of the main sewers first. Of course, it was not very often that the opportunity occurred. Usually sewers had to be fitted in on work that had been done by other people, but, when new areas were being laid out, it would be a good thing if engineers pressed the town planners—who were mostly architects—to let them choose their main drainage lines first. He had had an opportunity of putting into practice, because in the town where he was now working he had to do the work of both architect and engineer, and he had found that, after providing for the main traffic routes on the most direct lines possible, and laying out the main drains to give good, easy drainage right through, he was able to obtain good traction lines, good distribution of traffic, very easy distribution of water, and very easy distribution of lighting.

Mr. Klaarhamer (Amsterdam), replying to Mr. Eddy, with regard to the influence of ground-water upon sewers, said he had no technical

experience, and could only refer to what everybody with common sense could see in Holland if they kept their eyes open. The sewers were mostly affected by the very weak condition of the soil, and they would crack sometimes. As the sewers were nearly always laid beneath the ground-water level, especially in the old cities, the water percolated into the sewers, and therefore, they had not only to pump out the sewage, but also the ground water. Describing the nature of the soil in Holland, he said that first there was a layer of clay, then a layer of peat, and underneath that there was sand. When putting up buildings they had to make the piles just touch the layer of sand, and they had to do absolutely the same with the sewers. With sewers of large dimension they had to drive piles and make a proper foundation, in the same way as for a brick building, and that was very expensive. Along one of the canals, in Amsterdam, all the houses had timbers underneath to support them. There were very deep trenches, sometimes six or eight metres deep, and on the bottom of those trenches the sewers were laid. That also was very expensive work. As to the quality of cement, he knew nothing about it, except that the Dutch people recognised that everything that came from England was absolutely superior. Sometimes they had laid cast iron pipes in Holland, but had found that, when laid in the peaty soil, they had absolutely rusted away even in six or seven weeks. Therefore, they dug small trenches, into which they put sand, and when the pipes were laid in that sand they remained good for many years. With regard to gradients, the practice in Holland was to give sewers a slope of five millimetres per metre. At Middleburg there was a canal, the level of which always remained the same, except that they sometimes allowed it to fall a little when they wished to drain away the sewage which had been let out into it. Most of the cities in Holland had no open connection with the sea, so that most of them let their water into the rivers, which rivers maintained practically the same level, except near the sea.

Mr. Cotterell (the Chairman) said there was no doubt that in Holland they met with exceptional difficulties in connection with sewerage; when it was remembered that they could not dig down more than three feet without getting into water, it was surprising what the Dutch did manage to do in the way of laying and maintaining sewers. There must be great difficulties in connection with the disposal of sewage.

COMBINED SYSTEM OF SEWERAGE WITH LIMITED RAIN-WATER INLET.

By Walo von Greyerz,

Consulting Engineer, Vattenbyggnadsbyrån, Stockholm.

The combined system of sewerage is justly praised for its simplicity and efficiency. On the other hand it has been subjected to legitimate criticism.

Thus from a hygienic point of view it is objected that in the event of unusually heavy rainfall sewage enters the cellars, unless the conduits are designed to carry off the greatest possible volume of rain-water.

Latterly, in order to reduce the risk, combined systems have often been designed with larger dimensions than usual, for the automatic rain-gauges have shown that the highest rates of precipitation and their duration are considerably greater than was formerly supposed. Where several years ago a sewerage system was designed on the basis of a rainfall of 10 minutes' duration with a maximum rate of e.g. 100 litres per second per hectare (1.5 cubic feet per second per acre), the rate has since then been found to be perhaps twice that amount.

The consequence has been that in designing sewerage systems nowadays—especially for smaller communities, but also for the peripheric parts of larger towns and cities—the cost of adopting a combined system has been found to be so great that recourse has been necessary to a separate system, in which the rain-water is to the greatest possible extent carried away above the surface. And in denser populated districts, where the carrying away of the rain-water underground is indispensable, it has been necessary, in order to avoid prohibitive expense, openly to submit to the conduits of the combined system being designed on such a scale that they become flooded perhaps every other year or even oftener, unless it has been preferred to avoid this nuisance by constructing a duplicate system with entirely separate conduits for sewage and rain-water.

The strongest objection, therefore, to the combined system of sewerage is that it is *not hygienically irreproachable*, if, for the sake of reducing the

cost, the size of the conduits has been reduced to such an extent that flooding of the system may occur ; and that it is *too expensive*, if the conduits are so liberally designed that flooding of the system and resulting hygienic risks are out of the question.

These drawbacks are due entirely to the fact that in the case of especially heavy rainfalls too large a volume of water per unit of time is introduced into the conduits of the combined system. Such rainfalls, however, occur comparatively rarely and are always of very short duration. Therefore, though on these occasions the rate of run-off is apt seriously to overtax the system, the total run-off during the rainfall, expressed as a volume of water, is fairly moderate.

This circumstance has led Hugo Lindquist, C.E., of the Vattenbyggnadsbyrån, to the idea of relieving the combined system from the said peak loads by *arranging the gullies for a limited rain-water inlet and utilising the storage capacity of the streets to hold the surplus run-off.*

If, in the case of unusually heavy downpours, the flow of water to the gullies should be larger than the quantity they are able to cope with, the rain-water is held up in the street, which is thereby flooded to the depth of an inch or two to the width of some few feet from the sidewalk. When the rate of precipitation slackens after a few minutes, the water quickly disappears through the gullies. The flooding in the street can be estimated with sufficient safety, and the capacity of the gullies adapted accordingly in such a way that, even in the case of the most violent probable outburst, the flooding will not be greater than permissible in consideration of local conditions.

As with this arrangement the rain-water run-off to the combined system is limited by the gullies to a fixed quantity, the dimensions of the conduits can be designed with the same certainty as the dimensions of a separate system : damming up of the water in the conduits in the case of unusually heavy downpours and the consequent flooding of the cellars with mixed sewage and rain-water is, therefore, obviated with this system.

Moreover, as the technical arrangement for limiting the run-off through the gullies is the simplest conceivable—limiting the openings in the gratings according to conditions—it may be said that "*the combined system with limited rain-water inlet*" *unites both the simplicity and efficiency of the combined system and two of the advantages of the separate system, namely freedom from the risk of getting the cellars flooded and reduced cost of construction of the conduits.*

In conformity with the principles above outlined a sewerage project has recently been designed for the little town of Falkenberg (about 5,000 population) in the south-west of Sweden. From this project some figures may be quoted below for the purpose of illustration.

From observations of the automatic rain-gauges at Gothenburg and Malmö over a long series of years it is estimated for Falkenberg that various rates of precipitation have the following average duration and frequency :

Duration, minutes.	Rate of precipitation.				
	Extremely seldom.	Litres per second. per hectare.*			Exceeded.
		Every second year.	Once a year.	Twice a year.	Ten times a year.
5	328	230	188	143	80
10	192	135	109	64	35
15	133	94	78	58	24
20	101	71	58	44	18
30	70	49	40	31	13

It was further decided that the capacity of the gullies should be limited to such a quantity that damming up of the surplus water in the street should be allowed to occur once a year to the top of the kerb-stone. In the case of exceptionally violent cloudbursts, which occur at still greater intervals of time, damming up an inch or two above the top of the kerb-stone during a few minutes was considered permissible. In any case during the short duration of such a cloudburst scarcely any pedestrian remains in the street. The pavement is presumed to slope somewhat towards the gutter, so that in any circumstances there would be no risk of the water entering through the cellar entrances and doorways.

The determination of the rate of precipitation for which the gullies had to be designed, was effected by graphical computation, supposing square blocks of buildings, with a side-length of 100 metres (110 yards), situated with the streets at an angle of 45° to the direction of the surface-slope. With such an arrangement of the streets the quantity of water which the gutters have to carry off, is greater than if one half of the streets were parallel and the other perpendicular to the profile-slope. A more unfavourable case than that investigated would occur, it is true, if a street were carried along the bottom of a depression in the ground, but as this is not the case anywhere in Falkenberg, it was not investigated.

The investigation was made for such rates of precipitation as will be exceeded only once a year, and for streets with considerable, average and slight slopes, i.e. about 1 : 20, 1 : 80 and 1 : 300 respectively.

When in the case of a heavy downpour the water arrives at the gully at the lowest point of the block in larger quantities than the gully is capable of coping with, the gutters and the road-way in the neighbourhood of the gully are filled, and finally the surplus water flows over to the gutters of the block next below.

If the ground has a good slope and the district is densely populated and has streets and yards with non-porous surface, the rain-water from the block runs away so quickly that the surplus water flows over to the gutters of the next block while these are still filled with the rain-water from their own block, thereby increasing their run-off, so that the surplus water near the gully at the lowest corner of this block flows over to the third block, and so on. Finally, however, the surplus water, upon its

* 100 litres per second per hectare = 1.43 cubic feet per second per acre.

arrival in the gutters of the neighbouring block finds them empty or but partly filled, as they have already discharged the water which has run off from their watershed or the nearest part of it during the short cloudburst. The maximum of the damming up in the street is then passed.

When the ground is level or slightly sloping, the run-off is of course slower, and also the discharge capacity of the gutters is smaller on account of their slighter slope, but, on the other hand, in this case the street can store a greater part of the rain-water, through which the run-off of the surplus water to the neighbouring block is both delayed and reduced in quantity.

In the case of a slope of 1 : 20 a normal gutter has a discharge capacity of about 150 litres per second (5.3 cubic feet per second). The investigation showed that, in spite of the fact that in the streets of the three uppermost blocks rainfalls of 5 minutes' duration, corresponding to a rate of precipitation of not less than about 190 litres per second per hectare (about 2.7 cubic feet per second per acre), cause the greatest run-off, the gutters in these streets nevertheless are not filled to the top of the kerb-stone, even if the gullies have a capacity corresponding to only 40 litres per second per hectare (about 0.6 cubic feet per second per acre). In the streets of the fourth and fifth blocks, on the other hand, rains of 10 minutes' duration, corresponding to a rate of precipitation of about 110 litres per second per hectare (about 1.6 cubic feet per second per acre), prove to be determinative, and furthermore the investigation proved that here it was necessary for the gullies to have a capacity of 65 litres per second per hectare (about 1.0 cubic foot per second per acre), if the rising of the rain-water above the kerb-stone was to be prevented.

In streets with a slope of 1 : 80 and 1 : 300 a normal gutter has a discharge capacity of about 75 and 37 litres per second (about 2.6 and 1.3 cubic feet per second) respectively, and here rains of 10 and 15 minutes' duration respectively are determinative. In these cases the gullies must have a capacity corresponding to a rate of precipitation of 40 and 20 litres per second per hectare (0.6 and 0.3 cubic feet per second per acre) respectively.

In view of the uncertain factors that cannot be avoided, and the many special conditions in practice that cannot be considered in a general computation such as this, it was considered prudent to design the gullies for rates of precipitation somewhat greater than those computed, viz.:

Rate of precipitation.		Rate of precipitation.	
Slope of street. Per cent.	Litres per sec. per hectare.	Slope of street. Per cent.	Litres per sec. per hectare.
0	30	20	63
5	42	30	71
10	51	40	76
15	58	50	80

These rates ought to be further increased somewhat in such places as have a particularly unfavourable situation with respect to their discharge capacity, as for instance where steeply sloping streets suddenly abut on to streets with a much slighter slope.

With respect to the general configuration of the ground in Falkenberg the town was divided into three districts, within which the gullies were designed for a *rate of precipitation* of 70, 60 and 50 litres per second per hectare (about 1.00, 0.86 and 0.72 cubic feet per second per acre) respectively.

The factor of run-off by which these rates of precipitation had to be multiplied in order to get the capacity of the gullies depends on the nature of the watershed, and was computed with regard to the various manners of building which were prescribed in the town-plan for different parts of the town. For the town as a whole this factor was found to be on an average 0.4, and the corresponding *rate of run-off* through the gullies consequently was 28, 24 and 20 litres per second per hectare (about 0.40, 0.34 and 0.29 cubic feet per second per acre) respectively.

In order to limit the run-off through the gullies to the last-mentioned amount with the heaviest rainfalls that occur on an average once a year, it is only necessary, as was remarked above, slightly to modify the normal type of cast-iron gully grating adopted by the Swedish Association of Municipal Engineers, in such a way that the gratings are manufactured with one or more openings left out. A series of a few sizes only with different inlet-area is thus obtained, each one corresponding to a certain discharge through the grating at a water-level above the same equal to the normal depth of the gutter, e.g. 6 inches. On the sewer-plan is entered the size of grating which most nearly corresponds to the above computed rate of run-off. All that the engineer afterwards has to do when a new gully is to be set, is to order a grating of the size indicated on the sewer-plan, possibly with the modification that if another street gully or yard gully is arranged within the watershed of the gully indicated on the sewer-plan, all the gullies mentioned must have the inlet area of their gratings correspondingly reduced.

In the case of the most exceptionally violent cloudbursts which may possibly occur, the water is expected to rise, as was said above, only an inch or two above the kerb-stone. Finally the dimensions of the conduits are designed for the corresponding, somewhat increased, discharge through the gullies, together with the sewage and ground-water run-off.

With the arrangement as outlined above it was estimated, as far as Falkenberg is concerned, that a certain amount of flooding of the gutters will occur only from 4 to 6 times a year on an average. During some years a few more floodings will occur, other years a few less; each time they will last a few minutes only. In streets with considerable slope the water does not reach the top of the kerb-stone even in the case of the most violent cloudburst; in streets with an average slope the water rises once a year to the top of the kerb-stone, and for a few minutes

in a decade to an inch or two above that level. In slightly sloping or level streets the floodings last somewhat longer, but are on the other hand more moderate, not reaching the top of the kerb-stone even during the most violent cloudbursts.

The conditions dealt with above refer to finished blocks. Before the building on the blocks, as indicated by the town-plan, is finished, the run-off, and consequently also the flooding in the streets, is of course less in frequency as well as in amount.

By adopting "the combined system with limited rain-water inlet" smaller towns can effect a considerable saving in the construction of their sewers. In larger cities it may be necessary to make the conditions as to permissible flooding in the street more stringent; naturally the saving is then correspondingly less. But in all circumstances the invaluable hygienic advantage is gained that the danger of sewage entering the cellars is eliminated—provided, of course, that the conduits are properly designed and constructed, and that the inlet openings of the gully gratings are not made larger than those for which the conduits have been designed. The inconvenience of the rare and transient floodings of rain-water in the streets ought to be without practical importance—provided that the streets are constructed with such cross-sections of road-way, gutter and side-walk as have been assumed in the computation of the capacity of the gullies.

Finally, it may be mentioned as a theoretically interesting corollary to the above that, in adopting the method of computation outlined, *a natural factor of reduction for slighter sloping ground* is introduced. In using the above-mentioned factor of run-off only the surface quality of the watershed is considered, while in reality the rate of run-off evidently decreases in the case of less sharply sloping ground. In designing sewerage systems hitherto, a factor of reduction for the slope of the ground, estimated more or less at random, has sometimes been introduced ; this not very satisfactory procedure may with advantage be replaced by the above outlined rational method.

DISCUSSION.

Mr. C. G. J. Ratcliffe (Swanage) asked the author how he was certain that he only got the limited amount of rain-water which he provided for. Unless the sewers were made tight, a larger quantity than the limited amount allowed for surface water gained access to the sewers, and the original design of the engineer was defeated unless the sewers excluded subsoil water.

Apart from the failure of schemes through the in-leaking of the subsoil water there was also to be considered the question of the danger to health

through the pollution of the subsoil caused by the escape of sewage from the sewers.

He would, therefore, suggest that information on the practice adopted in the various countries for testing sewers merited some attention. He would like to know what was the general English practice, and the practice in other countries, so that they could compare notes on the testing of sewers after they had been laid. The best laid schemes of engineers were likely to go astray if there were an exceptional amount of subsoil water gaining admission to the sewers.

Mr. F. C. Temple (Jamshedpur, India) said that the system described in the paper had been in existence, in a slightly different form, in India for a long time. So far as he knew, the only town in the East which had attempted to deal with all its storm-water underground was Colombo, and it had an enormous separate system. Practically all Indian towns had a combined system with a limited inlet, and the method of calculating the size of the sewers, as a rule, was to reckon what was the least probable amount of water that they must take into the sewers—the unavoidable amount. The figure adopted for a large part of Calcutta, and in a large number of other places, was a run-off of one-twentieth of an inch of rain-water per hour. Whatever the size of the drains, therefore, it was certain that not only must the gutters at the sides of the streets be flooded, but the whole of the streets would be flooded, because the rainfall was enormous. He had actually seen a fall of 4 inches in an hour, 7½ inches in two hours, 15 inches in 12 hours, and 20 inches in 18 hours. Nobody could construct sewers to deal with that. He had been working for a long time to see if he could arrive at the best size of sewer and the best size of surface drain. Where there were sewers, as a rule he connected from surface drains by automatic cut-off gully traps into the sewers. One that had been used a good deal lately was his own, in which a ball floated up into a circular space as the water rose in the surface drain, and cut off the flow into the sewer. A very great deal of India was drained with open surface drains, which took foul liquid as well as storm water. The sizes used were as a rule calculated for a run-off of a quarter of an inch per hour for small drains and half an inch for large drains, and the main collectors usually one inch per hour.

Mr. Arthur J. Martin (Past President) congratulated the author on the rational method which he had adopted for keeping down the size of his sewers. He (Mr. Martin) had recently visited Cristobel, Mexico, at the Northern end of the Panama Canal, and had seen the conditions there. In the early afternoon of a very fine day, there would suddenly be a deluge of rain. He had seen the piccanninies bathing on the side-walks and in the gutters, in some inches of water ; and in the course of an hour or two the water had run off, and the streets were perfectly dry. He had had a case of the same kind to deal with, where they had, not a combined system, but a separate system, with independent drains for

surface water, with frequent outlets into the river. There was sometimes as much as three inches of rain in an hour, which the drains could not be made large enough to take. The whole city was practically flat, with a maximum level of only four to five feet above high water in the river, and it was physically impossible to carry off all the rain as fast as it fell. He had recommended, therefore, that the water should be allowed to pond up in the streets. That might not sound quite the thing, but, as the author of the paper had pointed out, the inconvenience due to the flooding of the streets was comparatively slight. He (Mr. Martin) agreed with that view, because, when two or three inches of rain fell in an hour, people did not promenade in the streets, but remained under cover, and at such times it could be taken for granted that the streets would not be required for any other purpose than to accommodate the surface water. He was endeavouring to get the streets themselves laid out with a slight fall towards the river, to carry the water off. He could quite understand that the author's system was admirable where there was practically no difference in level. He had not gathered whether the author limited the application of this method to such cases; but he could see a difficulty in applying it where there were considerable differences in level, and where possibly the surface water from the higher regions would flood the low-lying areas.

Dr. G. S. Coleman (University of Manchester) said that, in Manchester, the combined system of sewage was generally in vogue. In certain parts of the administration area the separate system was in use, but that was because, before incorporation into the city, that area had been compelled to pay for disposal of its sewage by another drainage authority.

In the centre of the city it was generally impossible to have the separate system as the rivers frequently rose above the levels of the sewers, and on this account many of the storm overflows originally constructed had had to be closed. Owing to the short-sighted policy of previous generations the river had been confined in too-narrow and very winding channels, thus causing great variations in the water-level, and this could have been easily prevented before the city became built-up and land was so valuable.

Although flap valves had always been installed on the outlets to the rivers and were properly looked after, it was found that in most cases they were useless to prevent the entry of river-water to the sewers, owing to the presence of floating debris brought down during flood time. After long experience of such work the speaker would urge that such overflow channels should never be constructed unless the outlets would always be above any flood level in the stream. In Manchester it had led to enormous quantities of flood water reaching the disposal works from the rivers and temporarily disorganising the treatment.

This question forms a part of the problem of rainfall run-off which the speaker had had under careful consideration for many years. Such a problem, was, in his opinion, the most difficult as well as the most

important one in the design of a sewerage scheme. In Manchester it was so important that it had proved the controlling factor in the design of the sewers. The principal difficulty arose from the fact that what would be a suitable self-cleansing velocity in dry weather became an excessive scouring velocity during wet weather, largely due to the suspended silt which was churned up by the increased flow. If, on the other hand, the velocity was calculated on the maximum capacity, the sewer might become in normal times what used to be known as a " sewer of deposit."

Arising out of these considerations the speaker had evolved a method of calculating storm-water discharge which had been published by the Institution of Civil Engineers. It was usual in this country to admit the storm-water to the sewers even if it was soon afterwards discharged to an adjoining stream. Such overflowing was commonly allowed when sewage and storm-water together equalled six times the normal flow, but very widely, there was no hard and fast rule, the quality of the dry weather flow varying so widely, even in the same town. The overflowing was usually done by means of a sill running parallel to the main sewer and discharging to the storm-water sewer, the sill height being set at six times the normal dry weather flow. The speaker had lately investigated the discharging capacity of such side-weirs and had published a formula which would be found in the papers of the Institution of Civil Engineers.

The method of storing the storm-water temporarily in the streets as suggested in the paper just read had struck the speaker as very ingenious, but he doubted its applicability to towns in this country. His experience was that street gullies frequently got choked with debris and sediment, and he considered that this would neutralise any attempt at scientific control of the gully outlets. It would be an extremely difficult matter to calculate the storage capacity of the carriage-way, and once the flood reached the footpaths it might enter basements through gratings, coal-shoots, etc., and cause an enormous amount of damage.

It would also be necessary to ensure the complete water-tightness of the road surface, and such a scheme would probably prove impossible where a change of gradient formed a dip and thus caused a pond. In this country at any rate, many houses, especially of the poorer class, had their entrances very little, if anything, above the kerb level, and would thus be very liable to flooding which could not be allowed for with any degree of accuracy.

Mr. H. C. H. Shenton (Past President) said that he had had considerable experience in testing stoneware pipe lines, and he had very little belief in the excuse frequently made by contractors and workmen that water subsided during an ordinary test owing to the presence of air in the pipe. He had always found that if a straight length of pipe were filled with water with reasonable care, the water remained at a constant level after the drain was filled, and that when it did not do so, water was leaking away somewhere. If the joints in the pipe line were

left uncovered it was generally quite easy to find the leakage. He specified a maximum head of eight feet for the test pressure. Good workmen found no great difficulty in making a length of say 100 yards of twelve inch stoneware pipe water-tight with ordinary cement joints. How long such a pipe line would remain water-tight was another matter deserving careful attention: permanent water-tightness depended very greatly on the construction of foundations. More attention ought to be given to the manner in which sewers, for one reason or another, developed leaks after they had been laid and tested. He had found in many cases that old sewers and sometimes new sewers leaked and admitted a great deal of land water even though the joints had been well made. Pipes were injured through crushing, settlement, contraction and other causes, which ought to be very carefully taken into account.

Mr. Von Greyerz (Stockholm), replying to the discussion, referred first to the testing of sewers. In Sweden, he said, they did it very seldom. Usually they need not take the ground-water into account when constructing combined sewers, because the soil in Sweden generally was rather impervious, so the amount of ground-water was very small. The object of this paper was not so much to discuss the question of preventing the water from coming up from the sewers and flooding the streets—which would not occur if the sewers were made large enough—but rather the question of preventing the surplus water, which could be stored in the streets without nuisance for a few minutes, from getting down into the sewers and flooding them. If this were done the dimensions and constructional cost of the sewers might be materially decreased. The regular combined system, it was true, already worked to a certain degree in the way the speaker intended to obtain with "the system with limited rain-water inlet" as if there were too many gullies it was easy to diminish the openings in the gratings. The Society of Municipal Engineers in Sweden had adopted some standards for gratings, and there was a series of, say five to eight different kinds of openings. Mr. Martin was right when he had referred to the difficulty of adopting this system in an area where there were differences in level, and it was pointed out in the paper that if there were a steep slope followed by a lesser slope there was a dangerous point. At that point a larger amount of rainwater must be taken down into the conduit, and the conduit had to be larger at that point. In a slope of, say one in twenty, when the rain-water came from one block to the gully at the lowest point of the block, the street was soon flooded, and the rain-water went on to the next block. It went so quickly, however, that the rain-water at the next block had not had time to run off, and therefore, it went on to the third, fourth or fifth block. By that time sufficient time had elapsed for the rain-water from the sixth block to disappear, so that there was no more danger, and the maximum of the street flooding had passed. For particulars of various conditions at different slopes reference should be made to a paragraph in the paper on p. 173

Mr. Cotterell (the Chairman) said the author had introduced what was really a scientific attempt to regulate the amount of rain-water which must fall into the sewer from the streets. It took us a step further than anything that had been done in this country in that direction. It still seemed to him that it was better, where possible, to prevent the street water from mixing with the sewage, especially where they had to treat the sewage, as in most cases.

UTILISATION OF SEWERS FOR THE DISPOSAL OF SNOW.

By Erland Hedström,

Chief of the Department of Streets of the City of Stockholm.

A question of great economic importance for most towns situated in countries with a cold climate is how the snow in the streets shall be removed in the quickest possible manner. On account of the largely increased costs of transport—especially motor transport—which result when the streets are not efficiently and rapidly cleared of snow, the problem of effecting such satisfactory clearance of snow from the streets has become particularly pressing.

The financial aspect of the question is shown clearly from the following table of expenses for the removal of snow from the streets of Stockholm during a series of years.*

Year.	Snow Transport. No. of loads.	Snow Transport. Cost in crowns.		Other scavenging expenses. Crowns.		
1914	242,000	152,000	+	690,000	=	842,900
1915	878,600	531,000	+	903,100	=	1,434,100
1916	824,200	435,000	+	883,400	=	1,318,400
1917	601,900	430,000	+	1,011,300	=	1,441,300
1918	496,500	499,000	+	1,867,800	=	2,366,800
1919	167,000	320,000	+	1,888,600	=	2,208,600
1920	235,000	404,000	+	1,974,000	=	2,378,000
1921	144,000	202,000	+	1,899,300	=	2,101,300
1922	688,500	645,000	+	1,701,000	=	2,346,000
1923	469,700	460,000				

In connection with this very wide and important question of rapidly and economically removing snow from the streets, I would specially touch upon a manner of procedure which I believe has been largely neglected, although it would seem to be a particularly obvious method. I refer to the possibility of using the sewers.

* For purposes of comparison the table includes also the expenses of other scavenging work.

Usually when the precipitation is in the form of rain, it is the sewers which carry the water from the streets in a very simple manner, which seldom involves any extra expense whatsoever. It seems therefore to be an obvious resource to use the sewers also when the precipitation is in the form of snow. In this case the snow is conveyed to and tipped into ordinary manholes or into capacious openings in the sewers specially designed for the purpose, so-called snow-shafts. As the sewer-water, even during the winter, remains at six or seven degrees Centigrade above zero, there is nothing to prevent the snow thus thrown into the sewer from melting and being carried away, if the sewer-section is large enough and the flow of water in the sewers is sufficient.

My attention was only drawn to this method of removing the snow during a journey which I undertook in 1909, when I found it in use particularly in German towns.

Since then the method has been introduced in several parts of Stockholm where the sewers have been large enough (generally one meter in section), and the flow of water sufficient to melt the snow. In these cases no considerable difficulties have presented themselves, either through stoppage of the sewers or owing to increased costs of clearing them. It is specially to be remarked that the gravel which is abundantly strewn on the pavements to prevent pedestrians from slipping, and which has been tipped into the sewers together with the snow, has not led to any noticeable inconvenience.

This successful result of the application of the method in Stockholm, however, is probably largely due to the fact that the sewers have a relatively good slope.

As, on account of progressive building operations, the open spaces which can be used as dumping places for snow are gradually disappearing within the town proper, it is obvious that the removal of the snow is being rendered more and more difficult and expensive, and therefore other expedients must be found.

I have, therefore, considered the possibility of utilising the smaller sewers with a lesser flow of water, and also larger sewers in which the flow of water is too insignificant to allow of snow being discharged into them during the morning hours, but which could be utilised later in the day.

In order to promote the melting of the snow and to ensure its being carried away, special precautions would have to be taken to increase the flow of water, either by pumping into the upper reaches of the sewer unfiltered lake or river water, or by flushing the shaft with water from the mains in sufficient quantity to secure the carrying away of the snow. This is of course an economic question. But since water from the Stockholm mains can be provided at a cost of about 15 öre per cubic metre, and lake or river water can be pumped at a cost of only a few öre per cubic metre, whilst it costs on an average kr. 1:50 per load to carry snow to a more or less distant dumping place, it would appear that the flushing of snow through the sewers would be a paying proposition.

Among the advantages attached to tipping the snow into the nearest

sewer-shaft may be reckoned that it is unnecessary to use horses, of which the supply is limited, whilst instead a proportionately greater number of the unemployed generally met with in the winter, can be provided with work.

Further it is to be observed that, on account of the short distance to the sewer-shafts, the streets can be freed from snow much more quickly, with the result that it has not time to get tightly packed, when the process of removal is more expensive.

By a fortunate accident most of the sewer manholes in Stockholm which might be used for the tipping of snow, are not situated in the middle of the streets, but at the side, where stationary vehicles stand, so that snow-tipping would not in the least inconvenience the traffic. Otherwise snow-tipping would be impossible in certain places owing to the busy traffic of trams and other vehicles. The lesson to be learnt from this is the necessity of locating a new sewer, which is to be used for the removal of snow, in such a position that a manhole or shaft into which the snow is to be tipped can be so situated that the street traffic is incommoded as little as possible.

What I have set forth above I would summarise as follows :—

1. For the removal of snow from the streets the sewers should be utilised to the full extent which is compatible with economy.

2. Where there is a possibility of augmenting the flow of water in the sewers, either by flushing from the mains or by pumping in unfiltered water from rivers or from lakes, this possibility should be taken into serious consideration.

3. When sewers are laid, the advisability of constructing special snow-shafts should be considered.

4. If sewers are to be utilised for the removal of snow, especially from streets where the traffic is considerable, they ought not to be laid in the middle of the street, as is usual in many places, but at one side, for example in the space allotted to stationary vehicles.

I have wished to bring up the question of the utilisation of sewers for the disposal of snow for discussion in the congress, in order to have light thrown upon it from all sides, thereby to secure a firm foundation for the further discussion of the question to which it is, in my opinion especially entitled.

I would also suggest that, if possible, the congress should take suitable steps to secure that this question—so particularly important from the point of view of municipal economy and traffic problems—should be examined from all aspects and brought to more general notice.

DISCUSSION.

Mr. HARRISON P. EDDY (Boston, Mass.) said that the disposal of snow through the sewers was a method which had been in common use in the larger New England towns and cities for many years. This was confined, naturally, to the larger sewers. He did not know of any case in which water had been pumped into the sewers, or where a large flow had been diverted into the sewers, for the purpose of carrying off the snow, but undoubtedly in some cases that would be advisable if practicable. The only objection he had heard to the disposal of snow into sewers was that in some cases, where the slopes of the sewers were very slight, there had been a deposit of sand and other similar matter taken up from the streets with the snow. As a matter of fact, however, the same material got into the sewers during other seasons of the year, and there was no reason why it should give more trouble when brought in by the snow than when flushed in by the rain-water. The deposit of sand, etc., in the sewers, was generally not a serious objection to what was otherwise a very economical method of disposing of snow. It is, of course, important to introduce the snow slowly enough to avoid danger of causing stoppage of the sewer.

Dr. G. S. COLEMAN (University of Manchester) stated that it was not often in Manchester that they were troubled with heavy falls of snow, but that when these latter occurred the sanitary authority was accustomed to arrange for the utilisation of manholes on the main drainage system for the disposal of the material.

Such manholes were chosen so as to be distributed throughout the area and to be in convenient spots for tipping, preferably in a side street near a main thoroughfare, so as not to cause obstruction to traffic.

At these periods the Cleansing Department put on emergency gangs, drawn principally from the Labour Bureaus, and carried out the whole of the arrangements themselves, apart from the City Engineer's Department.

No difficulty had ever been experienced in thus disposing of the snow, but care had to be taken that the tipping was not done so rapidly as to clog the manhole shafts which were usually about two feet six inches square.

It is well known that the sewage is at a higher temperature in winter than that of the atmosphere in the street above and hence the snow melts rapidly as well as being swept away by the flow in the sewer. The only drawbacks occurring to the speaker were two. The first was the large amount of road detritus introduced into the sewer with the snow, especially when macadam was in use, and secondly the temporary high increase in the discharge of the sewer, due to the fact that the snow melted much more rapidly than the equivalent amount of rain would have run off.

The first drawback was not of much account in Manchester where the silt content was always fairly high, and the second only caused incon-

venience at the disposal works for a short time, and was largely discounted by the storm-overflow weirs.

He would inform Mr. Hedström and others interested in snow disposal that they would probably find it worth while applying to the sanitary authority of Frankfort-on-Main for a copy of a pamphlet on the main drainage of that important city. In that pamphlet were sketches showing special manhole chambers for the disposal of snow, which fell heavily practically every winter.

These manholes were constructed with large shafts which, as far as the speaker could remember, were about four feet square. At the bottom of the shaft was a long, broad, sloping platform onto which the snow fell and melted, and the resulting water passed to a sewer alongside the platform.

This latter sewer usually formed a branch or loop with a main sewer, the manhole being in a bay of an open space, or somewhere when the carts could easily back up and discharge their loads without inconvenience.

Mr. Von Greyerz, replying on behalf of Mr. Hedström, said he was informed that in Stockholm there was no difficulty in disposing of the snow—which fell in rather large quantities—in the conduits, and the reason might be that the conduits generally had comparatively steep slopes.

SANITARY WORK CARRIED OUT IN FRANCE DURING RECENT YEARS.

By B. Bezault,
Paris.

Sanitary questions which had previously been relatively neglected in France have made a great step in advance as a result of the war. Since the Armistice many schemes of sanitation have been designed and approved, if not executed.

The unfortunate necessity of rebuilding almost entirely a large number of towns in the devastated areas has compelled the municipalities to carry out works of sanitation.

The study of these works has caused it to be realised that the pre-war arrangements were too costly ; as considerable outlay was involved in the rebuilding of the towns it became necessary to adopt the most economical methods available.

For this reason the cesspool system of sewage disposal could no longer be adopted and sewage has had to be conveyed in underground pipes for treatment at a central station.

The Northern and Eastern Railway Companies were the first to recognise these facts when they found it necessary to reconstruct entire small towns to accommodate their employés, towns with from 1500 to 6000 inhabitants at Tergnier, Lille, Lens, Bethune, Amiens, Longueau, Hazebrouck, Laon, Valenciennes and elsewhere.

Before all it was essential to re-establish the railways in order to provide transport. The railway companies in erecting these small towns have provided modern conveniences, water supply, electric lighting, and the discharge by underground pipes of all domestic and human waste products with a sewage purification works by the sewer outfall.

The system of sewerage adopted in almost all cases is the separate system. The railway companies, after consultation with specialists

(still a rare case in France), have generally adopted the biological system of purification consisting of sedimentation tank or preliminary clarification, septic tanks, roughing filters and percolating filters.

The difference between this system and that generally employed in England is that the removal of the grosser solids in the sewage is carried somewhat further by more efficient arrangements in the tanks with sharper fall and cone-shaped bottoms which facilitate the deposit and the removal of the heavy matters in suspension and by channels at the surface which facilitate the retention of floating matters.

The period of sedimentation in the tanks is about four hours.

The roughing filters placed at the outlets from the settling tanks to arrest the small filaments carried out in the tank effluent prevent the choking of the percolating filters and give good results.

These roughing filters are designed to deal with about 4600 gallons per square yard per day, and the filter material consists of clinker as large as a fist. This material is renewed partially every three months.

In certain cases where considerable fall is available, it has been possible to discharge the septic tank effluent over a weir and cascade, whereby the effluent is aerated with good results.

The distribution on the percolating filters is effected in the ordinary manner either by fixed or moving sprinklers.

The cost of the maintenance of these installations is very small, usually one man is sufficient at a cost of about twenty francs per day.

The activated sludge method of treatment proposed for these cases has not been adopted on account of the high cost of maintenance due to the need of from two to three men per twenty-four hours.

The example set by the railway companies is about to be followed by many towns in the devastated areas and even by some towns in other parts of France. A large number of schemes have already been approved by the Superior Council of Public Health of France (nothing can be done without the approval of this council), which also allows State subsidies to be obtained for these works.

The law relating to betting at race meetings and games in clubs provides for the payment of relatively considerable sums which must be used for works of sanitation.

Among the schemes actually adopted by the Superior Council of Hygiène, the greatest number are on the biological system of septic tanks and filters. A few are by the activated sludge method, while others consist of the discharge without purification direct into large rivers or into the sea. Thus, at Lyons the sewage can be discharged into the river Rhone during about 300 days in each year direct without treatment and for the rest of the year after simple clarification.

The Department of the Seine which has made an experiment at Mont-Mesly with the Sheffield system of activated sludge treatment, does not appear to be at all disposed to adopt this method, which has not, and cannot, give more than insignificant results having regard to the character of the sewage to be treated.

The city of Paris (an administration entirely separate from that of the Department of the Seine) has adopted an experimental installation of the activated sludge process which will shortly be in operation at Colombes.

The results obtained at this experimental station will have important influence in France generally as other towns will follow this example.

However, as I stated at the outset, the question of proper sanitation has made great progress in France. A start has been made but the full practical results have not yet been attained on account of the financial situation, as the towns of the " Liberated " regions have given preference at first to the erection of houses.

When, however, the situation improves, when the credit of France, which carried the greatest burden of the war, will have become better, then numerous and important works will be executed with the object of improving the sanitary conditions of the population.

It remains for me to express the ardent hope that this more normal condition of affairs will arrive as soon as possible.

DISCUSSION.

Mr. F. C. Temple (Jamshedpur, India) referred to the statement in the paper that "The period of sedimentation in the tanks is about four hours." That seemed to him to contain a fundamental inaccuracy which had done extraordinary harm to the progress of the science of sewage disposal. As the paper did not say what the strength of the sewage was, it told them nothing whatsoever. In books on sewage disposal work reference was made continually to the total quantity of sewage and the period of rest in tanks. The fundamental inaccuracy was that the total quantity of liquid was treated as the sewage, instead of it being recognised that the sewage was in the water and that the water was the vehicle, and that the sewage to be disposed of was the organic matter. Within certain limits it did not matter whether that was carried in a large quantity of water as a vehicle, or in very little. There were limits, undoubtedly, but it had already been proved that the size of tanks could not be decided only by the period of rest according to the total quantity of water, and that the size of tanks should be proportionate to the user. The amount of organic matter that came in would depend on the number of users. That required some qualification, however, because different users in different parts of the world produced different amounts of nitrogen. The native on one side of India produced, he believed, ten times as much nitrogenous matter as the native on the other. There were also other qualifying factors which entered into the problem, and modified it, but they did not alter its essential principles. If the inaccuracy to which he had referred could be got rid of, a great deal of the talk about flexibility of tanks disappeared at once. If the tank were proportionate to the number of users, an increase in the quantity of water that came down in a storm would not, as a general rule, very largely increase the quantity of putrefactive organic matter to be disposed of. They all knew that the first run-off of a storm brought down a great deal of foul matter, but for the whole day it did not amount to very much as compared with the crude sewage. If the size of the tank were rightly proportionate to the number of users, the quantity of water could be increased, and the period of rest necessary in the tank would automatically be reduced, and would, in fact, take care of itself. Experiments had been carried out in India—which had not received the attention they deserved—showing that for a five-gallon sewage the best size of tank was that which gave a period of detention of seventy-two hours. He took every opportunity of pressing the point that they should drop the discussion of tanks in periods of detention and discuss them in terms of users, so that they might be proportionate to the amount of work they had to do.

The Conference then adjourned.

GRIT CATCHERS, SCREENS AND STORM WATER TANKS IN SEWAGE DISPOSAL WORKS.

From the Point of View of a Sanitarian in India.

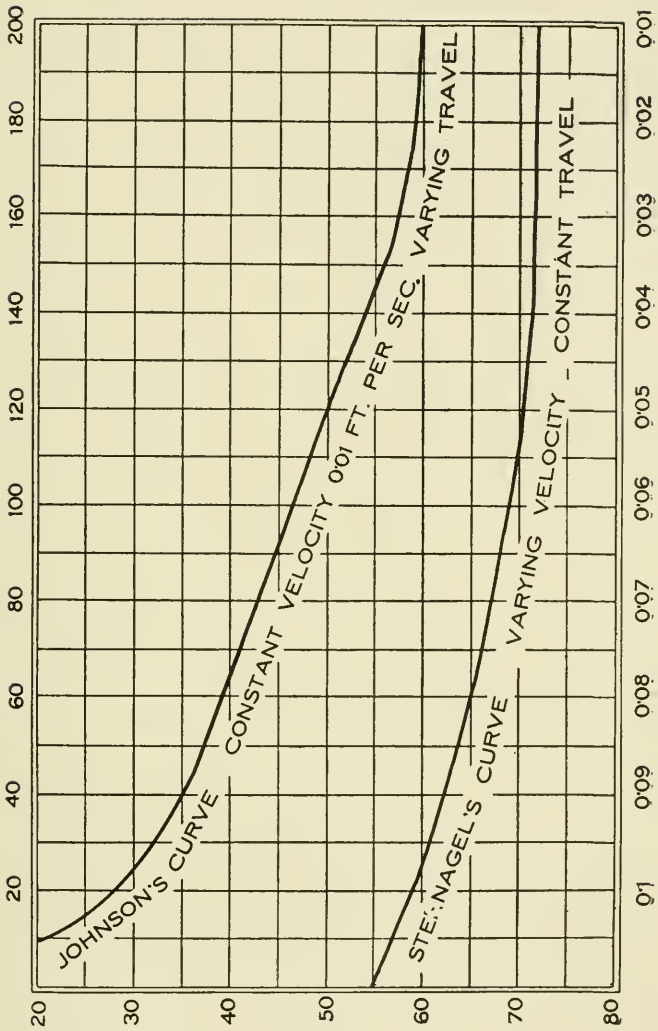
By F. C. Temple, Jamshedpur, India.

Books on sewage disposal and published accounts of sewage disposal works do not appear to discuss the subject of grit catchers (or as they are more often called detritus tanks), screens and storm water tanks, with the precision of thought that it deserves. There are numerous accounts (usually sketchy), of what various people have done ; but nothing is said of why they did it. And the Sanitarian, working in the uttermost parts of the earth, trying to discover rules by which to design his own particular installation, finds some rules for screens, none for grit catchers and several for storm water tanks, which on investigation prove to be unscientific and even wrong.

These notes are the attempt of a Sanitarian, working in India, to combine such information as he found available in print with his own observations, so as to define the first principles which should underlie the designs of screens, grit catchers and storm water tanks.

The information available was that screens are usually provided allowing $1\frac{1}{2}$ to $\frac{1}{2}$ inch openings (the vexed question of the use of fine screens, which are really a form of sewage disposal works, does not come within the scope of this inquiry) and that grit catchers have a capacity of $\frac{1}{100}$ to $\frac{1}{200}$ of the average daily dry weather flow (G. B. Kershaw in Sewage Purification and Disposal). A very few writers are beginning to discuss velocities through grit catchers. For storm water tanks there are the definite recommendations of the Sewage Disposal Commission Fifth Report), which are sufficiently important to require quoting at some length.

" We find that the injury done to rivers by the discharge into them of large volumes of storm sewage, chiefly arises from the excessive amount of suspended solids which such sewage contains and that these solids


JOHNSON'S CURVE
CONSTANT VELOCITY 0·01 FT. PER SEC.
VARYING TRAVEL
STEINNAGEL'S CURVE
VARYING VELOCITY
CONSTANT TRAVEL
20
40
60
80
100
120
140
160
180
200
20
30
40
50
60
70
80
0·1
0·09
0·08
0·07
0·06
0·05
0·04
0·03
0·02
0·01

can be very rapidly removed by settlement. We therefore recommend as a general rule :—

(1) That special stand-by tanks (two or more) should be provided at the works and kept empty for the purpose of receiving the excess of storm water.

(2) That any overflow should only be made from these special tanks and that this overflow should be arranged so that it will not come into operation until the tanks are full.

(3) In most cases it will probably suffice to provide stand-by tanks capable of holding one quarter of the daily dry weather flow."

No reason beyond rough experience is given for any of these figures.

Let us now attempt to arrive at first principles by considering the precise nature of the work to be done.

The sewage contains "suspended solids" which can "do injury" to the rivers and some of which can interfere with the operation of the biological disposal works, and do mechanical damage to the pumps (if any) through which the sewage must pass. These suspended solids may be divided into two main classes : floating solids such as pieces of wood, rags, paper and the like, and undigested fæces, and settling solids, such as mineral grit from the roads, sodden pieces of wood, paper and the like, and half digested fæces. The extraction and retention of so much of these solids as may interfere with the operation of disposal works, and of so much of them as is necessary to prevent injury to the rivers, is the essential work of grit catchers and screens, and of storm water tanks respectively.

The work of both grit catchers and screens on the one hand, and of storm water tanks on the other, is similar and only varies in degree. In both, floating suspended solids must be retained, totally, by baffles, from the rivers ; partially, by screens, from the disposal works, for the faeces must reach the disposal works through the grit catchers ; but must not reach the rivers through the storm water tanks.

The precise design of screens must be governed by the nature and quantity of the floating solids likely to come down with each particular sewage. In India (and apparently in many other places) a bar screen with 1 inch openings, followed by another with ½ inch openings, will stop all the floating solids that will do harm in the works, and will not retain the fæces and other organic matter which is to be treated in the works.

Again in both, settling suspended solids must be retained. These are held in suspension largely by the velocity of the flowing sewage and settle as soon as the velocity is reduced. The grit catchers and storm water tanks should therefore be so constructed that they will reduce velocity sufficiently to settle those solids which will do harm in disposal works and rivers respectively.

Two sets of experiments are on record. George A. Johnson published the following in his report on Sewage Purification, Columbus :—In a tank 8 feet wide and 7 feet deep, with a velocity of 0.01 feet per sec., 35 per

cent. of the suspended solids settled in the first 40 feet of the tank, 50 per cent. in 120 feet, 57 per cent. in 160 feet, and only 60 per cent. in 200 feet. Steuernagel's sedimentation experiments in Cologne gave the following results :—With cross-sectional velocities of 0.1 feet per sec. the removal of suspended solids was 59 per cent., of 0.06 feet per sec. 69 per cent., and of 0.01 feet per sec. 72 per cent. These two sets of figures are plotted together as curves shown herewith. Unfortunately Steuernagel's distance of travel was not available and presumably Johnson's curve would be a good deal flatter for a velocity of 0.1 feet per sec. They serve, however, to indicate that the path of the settling solids is a curve which descends steeply at first and then flattens out, and that the advantage gained by reducing velocity below 0.1 feet per sec. is small and below 0.06 feet per sec. is negligible. Grit catchers and storm tanks then must have a cross-sectional area sufficient to reduce velocity to the required figure and a length sufficient to allow the required percentage of solids to settle.

The settling solids which will interfere with the disposal works are almost entirely road detritus or mineral grit. Considerable Indian experience, which appears to find much support elsewhere, indicates that 1 foot per sec. is a sufficiently low velocity and 30 feet sufficient travel to settle all that matters. This is obtained very simply by F. W. Jameson in Pretoria, who widens out the end of the sewer approaching the works, to a flat bottom 6 feet wide, over which nearly 2 cu. secs. flow some 4 inches deep, or at a velocity of about 1 foot per sec. He has a drop at the end the object of which is not clear. A grit catcher made on his design is working admirably in India without the drop. (Many unintentional grit catchers of this pattern are to be found in the open drains so common in India, where a wide section is introduced too soon or too suddenly.) Actual sizes will be a cross-sectional area of about 2 square feet for each million gallons (or 2 cu. secs.) of average daily dry weather flow. The width will depend on the depth to be allowed, which will depend again on the method of cleaning to be employed. For small installations this design is cheap to build and to maintain, and very easy to clean.

A common form of grit catcher is a hopper-shaped chamber with the sewage entering at the centre and discharging over a circular peripheral weir. A variant of this, which seems to offer advantages, is to bring the sewage in on a tangent at the circumference and decant the liquid at the centre through a bell-mouth and bent pipe. The spiral movement given by the tangential entry allows little chance of stagnation of the sewage in corners or pockets, which must always be avoided, and the screens can be arranged as annular cages round the bell-mouth.

The proportion of settling suspended solids which must be retained by the storm water tanks to prevent injury to the river, will depend to some extent on local conditions. The most important function of the storm water tanks is the imprisonment of those putrefactive solids which might accumulate on the bed of the river and continue to give trouble, as they decomposed. During a storm, the river is probably flowing freely,

and therefore capable of removing much solid in suspension. Forty per cent. detention of the suspended solids will be ample in most places, and that can easily be ensured by means of tanks 120 feet long with sufficient cross-sectional area to reduce velocity to 0.1 feet per sec. If a greater percentage is to be detained, the cross-sectional area may be enlarged until velocity is reduced to 0.06 feet per sec. It is never worth while to reduce it below that figure. In many places tanks 80 feet long will be sufficient and it is never worth while to make them longer than 160 feet. Taking the former figure, each million gallons (or 2 cu. secs.) of storm overflow will require a cross section of 20 sq. feet; and the total capacity of the tank will be 20 sq. feet by 120 feet length, or 2,400 cu. feet or 15,000 gallons. If the average daily dry weather flow is one million gallons, and if the sewers are capable of discharging as much as ten million gallons per day over the storm overflow, over and above the maximum allowed through the disposal works, the storm water tanks capacity will be 150,000 gallons, or only $\frac{1}{6}$ of the average daily dry weather flow, as against the $\frac{1}{4}$ given in recommendation No. 3 of the Sewage Disposal Commission.

Storm water tanks built as simple septic tanks will be found convenient to work. There should ordinarily be two at least. Their length being 120 feet, as shown above, the width of each tank should not exceed 15 feet. The depth should not be less than 6 feet nor more than 15 feet. There must be enough tanks, side by side and operated in parallel, to give the required cross-sectional area. There must be a hanging baffle, extending from above highest water level to about 2 feet from the floor, to retain floating solids, placed across each tank, at a distance from the inlet about equal to the width of the tank, and there must be a scum board across each tank near the overflow weir, extending to not less than 2 feet 6 inches below top water level.

Contrary to recommendation No. 1 of the Sewage Disposal Commission, the tanks should be kept full of clean water. It is only when they are full that their complete action is assured, and it is only when they are kept full that it will begin as soon as storm overflow commences. The clean water will dilute the first run of storm water, which is usually the most foul. As soon as a storm is over, each tank which has received storm water should be pumped out, preferably into the sewer outlet at the entrance to the grit catchers. To avoid having to pump out more tanks than is necessary, the inlets to the storm water tanks can be arranged so that the tanks come into action successively as the volume of the storm overflow increases. In hot dry climates, the fabric of the storm water tanks will keep in better order if they are always full.

These remarks may be summarised as a set of rules :—

Place two sets of screens in the path of the sewage, the first with 1 inch openings, and the second with $\frac{1}{2}$ inch openings, sufficiently far apart to admit of easy removal of the screenings.

Ascertain the average daily dry weather flow, and provide grit catchers of sufficient cross-sectional area to reduce velocity to 1 foot per sec., and of such a length or shape as to allow 30 feet travel of the sewage in the

grit catchers. Provide stand-by grit catchers of the same relative capacity to deal in the same way with the maximum flow to be allowed through the disposal works.

Ascertain the maximum possible discharge of the sewer to the works, which is limited by the cross section and gradient of the sewer and the area that it drains ; decide the maximum quantity of this discharge which may be allowed through the ordinary disposal works ; arrange an overflow weir, above the inlet to the grit catchers, to draw off everything above that quantity ; and provide storm water tanks 120 feet long of such a cross section as to reduce the velocity of all that passes the overflow weir to 0.1 feet per sec.

Unless there is some unusual condition requiring unusual treatment, a plant designed on these lines appears likely to give satisfactory service.

DISCUSSION.

Mr. A. J. MARTIN said that Mr. Temple had done good service by calling attention to the really essential factors in tank design. We in this country were very much the slaves of habit of designing our sewage works. We used a very simple prescription, "provide tank capacity equal to so many hours' flow and so many cubic yards of filter." The form of the tank or the arrangement of the filter seemed to be a secondary consideration. There was a disposition to question the adoption of novel forms of tank or departures from the customary capacity, and to look askance upon subsidiary devices for the attainment of certain results. "Why not be satisfied to put in rectangular tanks to hold so many hours' flow?" Mr. Temple had done well to point out that it was not merely a question of capacity and that you could get better results by having regard to the question of velocity. He hoped to hear more from Mr. Clifford on the point of absorbing the energy of the incoming flow. It was quite possible to provide a tank which would take the required amount of sewage, and detain it for a given number of hours, and yet not get good results, because you had not got the state of quiescence at which you were aiming.

Mr. Temple had questioned our practice in dealing with storm water. We were accustomed to keep our storm tanks empty, in order that when a storm came along they might be filled with storm water, and that no overflow should take place until they were full. Mr. Temple suggested that they should be kept full all the time with clean water. It was not clear how he would get the clean water, unless it was from the last stages of the storm, when the surfaces contributing storm water had been fairly well washed. That was an arguable proposition. It might be better, instead of having an empty tank waiting to receive storm water, that we should have a tank full of comparatively clean water, so that the first discharge should consist of the foul storm water diluted with the clean water already in the tank. He (Mr. Martin) was rather disposed to keep his storm tanks empty, because he thought it a very important matter to delay the operation of a storm overflow. He did not rely solely on his storm tanks, for he invariably provided in his ordinary tanks a reserve capacity between the ordinary working level and that of the overflow, which might be a foot or eighteen inches in depth. That reserve capacity, taken in combination with the quantity treated in the ordinary filters, often enabled him to prevent any storm overflow whatever. A part of the storm flow was dealt with by the ordinary works, which were capable of treating three times the dry weather flow. The excess beyond that headed up in the tanks, sedimentation or septic as the case might be. This enabled him to take care of a very big flow indeed, perhaps at ten times the dry weather rate, in his ordinary tanks and filters; and then, if he had his storm tanks empty, he had a further storage capacity before any overflow could take place. The visiting engineers might be surprised to hear of the way in which storm overflows were sometimes arranged in this country. The overflow weir was actually

placed at the outfall at the height to which the outfall sewer would be filled by the flow, three times the dry-weather flow for instance, which it was desired to treat in the words. It seemed to be assumed that the depth of flow at the outfall would be the same as it would be say a mile back, leaving out of account altogether the drop that took place in the surface of the sewage as it neared the outfall. He regarded it as a mistake to have an overflow which depended on the rate of flow in the sewer at any moment. On a small sewerage system your dry weather flow might at certain hours in the morning reach three times the average dry weather rate. If you had an efficient flushing tank near the outfall, you might get six times the dry weather rate, or even more. Mr. Temple had rendered a great service by calling attention to the somewhat narrow and conventional views which were prevalent in this country.

Mr. W. H. Makepeace (Stoke-on-Trent) said he had listened with very great interest to the explanation of the paper given by Mr. Temple, also to the opinions of Mr. Martin in reply to that paper. Mr. Martin referred to the point raised by Mr. Temple, but did not say under what circumstances the detritus tanks were designed—whether in view of a separate system of sewerage, whether it was a partially separate system of drainage or whether it was a combined system. He (Mr. Makepeace) could assure Mr. Temple and Mr. Martin that, from his experience with the Ministry of Health this last two or three years, they were extremely alive to the very important point of what was the best way the detritus of a town or district could be dealt with in detritus tanks. Generally speaking, most people concerned with sanitary methods in this country, knew that the requirements of the Ministry of Health were very elastic in that respect. They gave the sanitary engineer something to work on, but left it for his experience and guidance to lay down a policy as to the best way of dealing with the detritus or grit coming down to the works according to the experience of his own particular district. The Ministry said he must have two or more detritus tanks each of not less capacity than one-hundredth of his flow : they left it to him to design and substantiate the necessity of having detritus tanks of greater capacity. Speaking broadly, he (Mr. Makepeace) found by experience that two or more tanks, having a capacity each of one-seventy-fifth of the dry weather flow, was for general purposes sufficient. But no sewage engineer would think of laying down a scheme of sewage disposal from general lines. He would look at the peculiar features of the district, and consider what had to be coped with and what was best in the way of tank design in the circumstances of the case. He (Mr. Makepeace) was certain there were no two sets of detritus tanks alike, designed according to these circumstances in this country. His experience in detritus and storm water tank design was that very careful consideration had been given to it. Certainly there was room for improvement, and almost every time he had the opportunity of discussing the matter with friends concerned in the business, he found that

improvement was taking place. For instance, there was a growing feeling that the storage tank capacity for storm water—of one quarter of the dry weather flow—was not sufficient and ought to be increased, probably because the first discharge of storm water was usually more foul. But if there was an exchange, or the possibility of more than one or two storm water tanks being provided, it rested very largely with the management of the works as to whether they allowed that very foul washing of the sewers to get into the stream at all. The same thing applied to detritus tanks. With regard to the velocity and size of the detritus tank, he agreed it ought not to be larger than sufficient to drop the solid matter which was brought down—that solid matter, whose specific gravity Mr. Temple agreed would vary considerably according to the township in which the scheme had to be designed. In his town there was a trade whose principal waste consisted of finely divided clay. The specific gravity of clay was very high, but owing to the finely divided nature of this waste, it took a tremendous amount of precipitation before it could be got down to be safe to carry to the filters. He had been obliged to put down detritus tanks very much larger than would be usual in normal cases, even 120 feet long ; and yet these would allow the organic matters to pass through quite sufficiently to maintain the enormous strength of the sewage from an organic standpoint. It was a very important point this question of detritus tank treatment and capacity, and also the storm water tank ; and he did not want Americans and others to think we were not alive to that subject in the way he was afraid Mr. Martin and Mr. Temple had been given to understand. We were very much alive to it. He could say from his own personal experience that the Ministry of Health were very much alive to it, and his friends concerned in the actual control and treatment of sewage would corroborate this. So far as concerned keeping the storm water tanks filled for the reception of storm water, he was afraid that was a very great mistake. If you had storm water tanks full of water, it must in actual practice be untreated sewage. This untreated sewage would not take very long to become septic and a very foul liquor. Immediately a storm arose you would be forcing that septic liquor direct into the stream. The proposed remedy was worse than the evil. If the idea was to fill the storm tanks with fresh water of a non-putrefactive kind, it might have distinct advantages, but there were very few works where that was a practicable proposition.

Mr. W. Clifford (Wolverhampton) said the expression "velocity of water in tank" had been used for the last twenty years without challenge, but the velocity of water in a tank had never been determined yet, at least not with any degree of accuracy, and if anyone knew how to do it, he would like to be informed. Trying in a glass tank holding about ten litres he had been able to determine it by a chemical method, utilising a curve and determining the centroid vertical of that curve, but in large tanks he did not think it had been determined anywhere. On one or

two occasions he had tried in a large tank by chemical means, and had obtained a result that seemed to be good ; but having tried in a laboratory on a small scale with a ten litre vessel, he had become more doubtful of his results in the large tank. The velocities usually given meant the average rate of passing through the tank, which was quite a different matter ; the motion in a tank might be very turbulent and yet the rate of going through the tank be quite a nominal amount. With regard to the length of a tank that was a secondary matter ; the main thing in sedimentation was to obtain quiescence or a streamline flow through the tank. Even in a small tank, with every care possible, there would be lines of flow in the tank that seemed to pass through the tank like a cloud, or in striæ or laminæ. Having obtained a liquid as quiescent as possible the next thing was the period of quiescence. No two liquids were alike in that respect, even the day flow would be largely different from the night flow of the same sewage. One hour's liquid might require twenty hours' quiescence and another only eight hours to get the same degree of settlement. A third might require only a few minutes, and the liquid being dealt with must be known before you could say how great a degree of settlement and how long a period of quiescence would be required. Average results would have to be taken because day flow differed from night flow. A sewage with a large amount of colloid, no degree of settlement would bring down more than 60 per cent. It would go septic before it would deposit in the tank. There was a limit to the amount of sedimentation obtainable even with absolute quiescence such as you would have in a laboratory vessel. With regard to storm water ; this was usually looked upon as a maximum of six times the dry weather flow. He wanted the Conference to look at it as not only six times the dry weather flow but as considerably more than six times the amount of energy. You had energy entering your tanks during storm times as much as ninety times that of the minimum flow. Your dry weather flow might be as one, and the storm water almost ninety times the energy entering your tank. That amount of energy had to be met ; it had to be destroyed or dissipated, or it would remove the sediment out of the tanks. If the water flowed through the tank it might almost be swept clean of the previously deposited matter. The absorption of this energy was a large question. It was not easily done. He had devised a storm tank which was exceedingly simple ; it was just merely a T piece and a well under the T piece. He was able to deposit the greater portion of the solids within about eight feet of that well. The T allowed the final settlement to fall as the tank allowed. The one point he wished to emphasise was that velocity in the strict sense of the term was distance over time, and if you were speaking of the rate of flow through the tank it was not necessarily the velocity of the liquid in the tank. Rate of flow was quite different from velocity.

Dr. Ardern said he thought that Mr. Temple was justified in raising the point he had done in the paper. His own experience with regard

to the design of grit chambers—he was not speaking of storm tanks—was not coincident with that of Mr. Makepeace. In the past, very little, if any, attention had been paid to the design of grit chambers, and he did not know that this had been essential until the advent of modern forms of sewage treatment. In the older schemes, if the grit chamber did not remove the heavier matter, this was removed in the sedimentation tanks. But with recent developments in sewage treatment this question of the removal of grit loomed as something very much more important than it had been hitherto, and for that reason he was personally satisfied that much more attention would have to be given in the future to the design of grit chambers than had been done in the past. He was not going into the question of the difference between the rate of flow through the tank and velocity, but the question of the number of units was of considerable importance. The mere fact that in very few works in this country were there more than two units of grit chambers showed that there had not been much attention given to this matter. Mr. Clifford had referred to the difference between dry-water and storm-water flow. Two units were not enough to maintain the constant velocity through the tanks which should be aimed at—constant velocity, no matter what the rate of flow arriving at the works. For this, very much more than two units were necessary. One point he would refer to was the position of the screen. He had been surprised to find in many even recent installations, that the screens were placed before the detritus chamber. He did not know for what reason. It seemed to him fairly manifest that the screens should come subsequent to the passage of the sewage through the detritus chamber. Another very important point that Mr. Temple had not touched upon was the design of the screen. In his (Dr. Ardern's) opinion we had a long way to go with regard to getting the most efficient type of screen. Our friends in America had done a lot more work with regard to screening of sewage than we had done in this country. He did not like the ordinary bar screen cleared by forks. This was most inefficient. In Manchester they were about to try a new form of screen, which it was hoped would give better results than had hiterto been obtained. With regard to the velocity required for the deposition of particular solids that must be governed to some extent by the character of the sewage. Sewage at different outfall works differed so greatly in character that you could not lay down any hard and fast rule.

Mr. Chalkley Hatton said he disagreed from Mr. Clifford on the question of the length of tank, and the velocity. He (Mr. Hatton) thought the amount of precipitation depended on the length of the tank. He had found in his experience of detritus tanks that, as Mr. Temple had shown, the greatest amount of precipitation occurred within a few feet after the sewage entered the tank. By giving more velocity throughout the tank and doubling the length of the tank, there would be considerable pick-up due to divergence of the current through the tank, and a

great deal of grit would pass over the sill if the tank is too long. He agreed with Mr. Temple in saying that thirty to forty feet was a great deal better than double that length.

Mr. W. Clifford (Wolverhampton) said the point he had referred to was the sedimentation tank as distinct from the grit tank. Sedimentation was largely a question of time and degree of quiescence. He agreed that over a certain length would not add to sedimentation, but you could have deposit in thirty or forty feet if time and degree of quiescence allowed for the deposition.

Mr. Temple (Jamshedpur) said he had been given a gratifying number of questions to answer. Dealing with Mr. Martin's question he certainly proposed that the storm tank should be kept full with clean water, and, if necessary, a main should be laid for that purpose. The total cost would not be very great, and the advantage gained would be enormous. Then Mr. Martin had asked why the tanks should be kept full. It was not until they were full that they could come into action properly, at any rate if they were as he would consider, properly designed. This brought in two or three other questions that had been raised. The purpose of the tank, as far as he could see, was to reduce the rate of flow or velocity, whichever it was called, to the figure at which the silt to be taken out would come down, and to make reduction of velocity as quick as possible. He had used Mr. Clifford's invention, and it was one of the most admirable things that existed for reducing the velocity quickly. As soon as the velocity was reduced to the proper point the silt would begin to come down, and in a curve more or less of the shape that he (Mr. Temple) had shown (p. 192). They were dealing with a continuous flow plant, and therefore the curve would be a falling one. The time factor was provided by the length of the tank. Mr. Clifford had said that the length did not matter, but with a continuous flow and with a properly proportioned tank the length would be of immense importance. He was not now dealing with sedimentation tanks, but with tanks of which the purpose was to take out settling solids which would do harm either in the disposal works themselves or on the bed of the river afterward. The former might be very heavy, but the storm tanks should take out comparatively light solids. As soon as the velocity was reduced, just as in an absolutely quiescent tank, the silt would begin to come down, and it would require time to come down, whether it was mineral grit or the solid matter of the sewage proper. Provided that the rate of flow was fairly even throughout the cross section of the tank, then the important factor was the length of the tank, which must be enough to provide for the time factor. That helped to answer the question as to why the tank should be kept full. He was supposing that the tanks were designed to deal with a really big storm ; and he was assuming that the rate of flow would be reduced at the beginning of the tank by some means or another to as nearly as possible the average rate of flow through the

tank. If the tank started by being empty, the sewage would not, it is. true, be overflowing until the tank filled up. It only began to overflow when the tank was full. But anybody who has watched a tank fill up, has seen all sorts of churnings, and that when the tank was nearly full, things quieted down. The full effective value of the tank was obtained immediately the storm water began to run if the tank was full, but not otherwise. The dilution from clean water in the tank was important, but if any storm overflow water was coming into action at all, the tank ought to work in what he considered was the way a tank should be designed to work—it should take out the silt that was going to do harm. He agreed with Mr. Martin that early overflow was not at all desirable. Mr. Martin himself said that he provided for the first part in the ordinary tanks, and that seemed to him (Mr. Temple) to answer the question about the desirability or otherwise of having any immediate overflow from the storm tanks, because it was almost certain that the first of the storm run-off would be dealt with in the ordinary tanks. Mr. Makepeace had asked a question as to whether the sewers were separate or combined, but he (Mr. Temple) was not discussing details in this paper. He was asking the Conference to come to general principles, and on general principles there would be no difference in the theory whether the sewers were separate or combined. The details would differ, but the general principles would remain the same. Mr. Makepeace had gone on with a statement that no sewage engineer would lay down a plant from general principles, but if no sewage engineer was to design from general principles what was the Conference assembled for? Its members were there to decide on general lines, and the skill of the engineer in a particular place would be shown in his application of the general lines to the special circumstances. Undoubtedly every installation would have to be treated on its own merits, but, seeing that the problem was very much the same all the world over, and must have certain common features, there must be some general underlying principles the definition of which would be a help to everybody. Engineers would not get very far in the science of sewage disposal until they established those general principles. In designing a blast furnace or an open-hearth steel furnace no one would say that it would be wrong to go on the general principles established by somebody else. Nor would he fail to say that it would be wrong to go on hard and fast lines. He would find out precisely what was the raw material he was dealing with, but his general principles would be the same. Mr. Makepeace had raised another question which he (Mr. Temple) had not brought into his paper, but which was very interesting, and that was dealing with finely divided clays. He had to deal with finely divided clay in very large quantities, which would not come down with any length of settlement, but would come down instantly on the addition of a coagulant such as alumino-ferric or activated sludge. When a special substance such as finely divided clay was to be found in the sewage, it required special treatment, and he thought special treatment apart from ordinary grit catchers. Sewage engineers had not solved this problem,

although in waterworks it had been dealt with successfully by means of settling tanks and coagulating tanks. In his (Mr. Temple's) sewage works the heavy silt was coming down in the first compartment of the aeration tank of the activated sludge plant, and that tank had to be cleaned rather often. He thought a possible solution was to have a small aeration chamber into which some activated sludge could be admitted before the sewage came to the main chamber, but that was a very special application which did not really come into the scope of his paper at all. With regard to Mr. Clifford's remarks, he was arguing on average rate of flow through the tank, and, as he had already said, the important thing was to reduce the rate of flow to the average rate of flow as early as possible in the tanks. He agreed with Dr. Ardern, that the number of units was important, but would modify Dr. Ardern's statement that the rate of flow through the tanks, at any rate of grit catchers, should be constant. He (Mr. Temple) would say it must never exceed a maximum. He did not think it could be worked so that it would be constant, but there should be enough units to come into action one after the other, and the action should be mechanical, not biological. As Dr. Ardern said, the rate of flow would vary in different places. What he (Mr. Temple) had given was an average that he had found actually used, in a very large number of places with apparently very different sewage and very different conditions. It was about one foot per second. He had taken that out of the collection of seventy-one different accounts of sewage works of which he had spoken the other day. The Chairman had asked concerning the deposit in grit catchers of small works, and he (Mr. Temple) could only give his experience in India. There they had cheap labour that could go on more or less constantly, and he had found that in very small works the most efficient grit catcher was to widen out the mouth of the sewer into two flat-bottomed channels about thirty feet long, in which the rate of flow did not exceed one foot per second. Once every hour or so a coolie started at the bottom and scraped upwards with a shovel. The grit and other matter that he collected was put into a receptacle and afterwards buried.

HISTORICAL DEVELOPMENT OF SEWAGE PURIFICATION PROCESSES.

By J. H. Garner,

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To trace the historical development of sewage disposal in all its aspects would not only be an interesting study but, I think, of great value, especially at the present time when it is obvious that sewage purification processes are in a distinct phase of evolution and when we may be on the verge of even greater developments.

Under such circumstances it is sometimes well to look back upon the steps by which the present position has been reached and to consider the successes and failures encountered on the way, taking heart or warning from the same in the constant endeavour to bring greater efficiency and economy to bear upon the very important national problem of sewage disposal.

It is to be hoped that someone of wide and lengthy experience, capable of drawing upon personal reminiscences, will undertake the task of writing a historical survey of sewage disposal, and in such a manner that it may easily be kept up to date as developments occur.

The writer, within the limited scope of this paper, merely intends to touch upon a few salient points which have attracted attention since it became clearly recognised that the prevention of rivers pollution is an indispensable requisite of modern civilisation.

The introduction of the water carriage system, while affording a satisfactory means of removing filth from the vicinity of dwellings, led to the discharge of the accumulated wastes to streams and so to the problem of having to dispose properly of these wastes in order to terminate the dreadful conditions into which many streams, especially in manufacturing districts, have passed.

Up to 1854 it had been held by the General Board of Health to be dangerous to spread sewage or even water on land, unless at a consider-

able distance from dwellings. Consequently, a number of towns, to avoid carrying sewage to land at a distance, or even at all, attempted to "disinfect" or "deodorise" it by the addition of chemicals such as carbolic acid, chloride of lime and chloride of iron, with the object of delaying putrefaction and the attendant odours until the sewage had been carried by the stream away from the neighbourhood of the town discharging it. These attempts were really the beginning of chemical treatment and chemical precipitation methods.

LAND IRRIGATION.

About this time Liebig took up the question of sewage treatment, and in addition to arguing that countries which discharged their sewage into streams would finally become impoverished agriculturally, placed values for manurial purposes upon town sewage ranging from 8s. to 18s. per head of population. Treatment of sewage by application to land was thus given a tremendous impetus, the question of danger to health arising therefrom became dropped, and chief interest centred upon the possibility of turning the manurial constituents of sewage to financial profit. Thus, in 1864 we find a commission stating that land irrigation was the only satisfactory method of sewage purification, and that neither mechanical nor chemical methods can render it non-putrescible. In 1866 and 1867, followed the Sewage Utilisation Acts, enabling local authorities to buy land for sewage treatment, even outside their own areas.

The opinions of Liebig and his exaggerated valuation of sewage, which was not realised in a single instance, were responsible for some of the difficulties of later years. By 1876, about sixty towns in England had tried irrigation, and many schemes had proved failures both financially and otherwise, chiefly because there was a clashing of economic and sanitary interests, which are often diametrically opposed, frequently because the land was quite unsuitable for the purpose and rapidly clogged and became coated with a layer of putrefying filth. In some cases the sewage contained trade wastes, harmful to crops, and more often than not, the management was of a low standard.

In face of such conditions, local authorities were again being attracted towards chemical methods, of which a great number came into prominence about that time, and were put to the test, especially where it was claimed that their adoption would bring about purification and also remove the manurial constituents of sewage, which could then be manufactured into a portable manure.

In 1868 a commission was appointed to obtain expert opinion upon the whole subject.

This commission again re-affirmed that only by land treatment could the dissolved organic matters be removed from sewage, but realised that there were difficulties inseparable from that method, and carried out experiments to overcome them.

INTERMITTENT FILTRATION.

Sir Edward Frankland, as a member of the 1868 Commission, was the first to submit sewage treatment to scientific investigation in the true sense. The early irrigation schemes had necessitated large areas of land, and Frankland's experiments were, therefore, devised with a view to increasing the volume of sewage which could be treated upon a definite area. Observation had already been made that in this respect fallow land was better than land under crops, but financial considerations, and the idea that *continuous purification* of sewage was dependent upon cropping, had obscured this.

Frankland, in his experiments, used glass cylinders 6 feet high by 10 inches diameter, filled with soils from several irrigation farms. These soils were dosed twice a day with London crude sewage at rates varying from three to fifteen gallons per day, according to the type of soil, and, after four months working did not show signs of becoming clogged. The effluents were non-putrefactive, clear and contained nitrates. It was concluded that with the best land, underdrained at a depth of 6 feet and divided into plots, dosing each in turn for six hours and resting eighteen hours, one acre could purify 44,000 gallons of sewage daily without fear of choking up the pores of the soil.

This system of periodical dosing and resting was designated by the commission "intermittent downward filtration."

In spite of the fact that no profit could accrue from this system (which was a serious admission at that time) and that there might be difficulties in distributing the sewage and some nuisance due to putrefaction on the soil surface, the Commissioners were so optimistic of its success as to venture the opinion that even concentrated trade wastes might be purified in this way.

The most successful exponent of Frankland's system was Bailey Denton, who constructed a number of land filtration works, mostly to relieve unsatisfactory irrigation farms.

Writing in 1877, Robinson and Mellis state that about forty towns had attempted to purify sewage by intermittent filtration, but the results were generally unsatisfactory. Dunbar has, however, stated that Frankland's rules were not adhered to in any one case, with the result that the system for the time became discredited.

We know from later experience that where a sufficient area of suitable land is available at reasonable cost there is no doubt that "intermittent downward filtration" affords a satisfactory system of purification, provided steps are taken to minimise the difficulties which Frankland foresaw.

ARTIFICIAL FILTERS.

In connection with intermittent filtration it had been observed that where the soil was sandy less trouble was experienced and more satisfactory results were obtained than with heavy soil. These facts suggested the construction of artificial sand filters. Some work in this direction was done by Baldwin Latham, who, in 1880, laid claim to an

improved system of intermittent filtration following upon contemporary scientific advances.

We are, however, indebted to the Massachusetts State Board of Health experiments, which began about 1886, for the development of artificial filters upon scientific lines and the demonstration of their practicability.

Before briefly referring to this work it will be necessary to mention a few scientific opinions bearing upon the question.

RISE OF BIOLOGICAL METHODS.

As early as their discovery about the middle of the seventeenth century, microscopic organisms had been identified with putrefactive action, but it was not known until later that they were the chief cause of the slow decomposition of organic matter.

Liebig (1840), concluded that the decomposition of organic matter was a process of slow direct combination with oxygen.

Frankland similarly assumed that the dissolved organic matters in sewage were directly oxidised by the oxygen of the air contained in the pores of the soil, as the sewage percolated through, and he likened the action of the soil to that of the lungs in breathing.

During the sixties and seventies great advances were made in bacteriology. Pasteur (1862), suggested that nitrification might be a biological action, and in 1877, Schloesing and Muntz, who had been asked to study the purification of sewage by land filters, not only proved that nitrification was due to organised ferments, but regarded it as essential to the purification process.

Sewage purification thus became recognised as dependent upon micro-organisms, and the presence of nitrates in an effluent was taken as an unmistakable sign that purification was well advanced.

Warington confirmed the work of Schloesing and Muntz, showed that solutions of ammonium salts could be nitrified by adding soil extract and maintaining free access of air, and in 1882 described his idea of a filter bed "having a greater oxidising power than ordinary soil and subsoil. Such a bed could be made by laying over a system of drain pipes a few feet of soil from the top 6 inches of a well cultivated field."

Duclaux (1884), ascribed decomposition of organic matter in all cases to the action of micro-organisms. He writes :—"They are the important, almost the only, agents of universal hygiene."

Keeping the above points in mind will facilitate a conception of subsequent developments.

CONTACT BEDS.

In the Massachusetts experiments previously mentioned, several grades of material were used for constructing filters, ranging from fine sand to coarse gravel. In the latter case it was soon found that intermittent filtration failed, as the liquid did not flow over the surface of

the filter but rapidly passed through the large pores without being purified. A layer of soil or sand placed on the surface did not lead to satisfactory results although distribution was improved.

During the years 1886–1890, renewed attempts were also being made in this country to filter sewage at a higher rate than was possible on land areas, and stone, gravel, ballast, coke and clinker were resorted to, in addition to sand.

To overcome the difficulties of distribution and too rapid passage of the sewage through the filters, Dibdin modified the usual procedure of allowing the sewage to pass continuously through the filter, by placing the material in a watertight tank, allowing the sewage to fill the tank, afterwards holding it "in contact" with the filter for some time to allow the oxygen in the pores to oxidise the organic matter. Next, the liquid was drawn off from the bottom of the filter, and the latter allowed to stand empty to be recharged with air.

Dibdin's modification of the process of intermittent filtration thus gave rise to the "contact bed" system.

Regarding single, double and triple contact, little need be said; Dibdin himself considered the action the same as in land treatment, but, he added, "land treatment, concentrated, accelerated, and controlled, and therefore economical; whilst land treatment as generally practised is haphazard, uncertain and expensive."

Dibdin's early experiments were with settled or chemically precipitated sewage, and the results were a great advance on anything previously accomplished.

At Sutton he succeeded in treating 750,000 gallons of sewage daily per acre by this process, with the production of a non-putrescible effluent.

Dibdin's development of the contact bed must, therefore, be regarded as contributing greatly towards a solution of the sewage problem. Not only so, but it came at an opportune time when little advance was being made in other directions.

Numerous towns quickly adopted the system, especially after Manchester had done so in 1890.

Unfortunately, exaggerated claims for the system were put forward, and these led to serious and costly mistakes being made.

Dibdin, himself, seems partly responsible for this. It is recorded that on the 17th September, 1896, he wrote in the visitors' book at the Sutton Works:—"Why not try putting large ballast in No. 1 tank and filtering crude sewage through it without chemicals? Bacteria will eat sludge, and save cost of pressing, etc."

How unfortunate does this suggestion seem in the light of later experience, and how much trouble and expense have similar statements led to since that time.

Clogging of the beds accompanied by deficient aeration has been the chief difficulty in connection with the contact system. Dibdin ultimately admitted these defects and tried to remedy them in his attempts to treat crude sewage aerobically by constructing primary

contact beds of slates, laid horizontally and spaced one or two inches between the layers. It is unlikely that many contact beds will be constructed in future, in fact they are in many cases being converted into percolating filters or activated sludge tanks.

PERCOLATING FILTERS.

Having found that covering the coarse filters with a layer of soil or sand was not conducive to good working, the Massachusetts experimenters, adhering to Frankland's original principles, tried to create a uniform flow of sewage through the coarse material by applying the liquid in small successive amounts. In this way they sought to prolong its passage sufficiently to allow oxidation of the organic matter, while there would also be more frequent opportunities of renewing the supply of air. Automatic devices arranged to discharge flushes of sewage on to the filters every half hour or so proved unsatisfactory, as they did not distribute evenly over the surface.

As distribution by means of a layer of fine material had failed largely because air was prevented from entering the filter, we find Waring (1891), and Lowcock (1892), endeavouring to overcome the difficulty and to improve aeration by constructing filters with false floors, below which pipes were laid through which air could be forced. Expense and the difficulty of uniform air circulation prevented further progress, but the experiments show that the importance of air circulation through the filter was fully recognised.

Early in 1893, Corbett, of Salford, who had been considering the Massachusetts results, developed the filtration process in a new direction. Corbett's ideas of distribution are said to have been suggested by observing rain falling upon porous soil. Whether this be true or not, all his experiments were directed towards effecting distribution in a similar manner. He also attached great importance to facilitating air circulation through the filter and with that object used evenly graded materials for their construction and kept the outlets open.

His early distribution experiments commenced with perforated pipes and channels laid, first, upon the filter and afterwards fixed above. In 1894 he tried revolving distributors, and the same year adopted the fixed spray jet, which is still doing excellent service at many works to-day.

It will be seen that Corbett's work constituted a distinct advance. In some experiments he succeeded in purifying about 500 gallons of chemically precipitated sewage per square yard daily, with a filter 5 feet deep.

Working independently, Wallis Stoddart, of Bristol, carrried out a series of important experiments from 1883 onwards, upon the filtration of sewage and liquids containing similar constituents. Stoddart emphasised the importance of free air circulation and the advantages of applying the liquid in such a manner that it flowed over the surfaces of the material in a thin film. Under these conditions he demonstrated

the important fact that the *dissolved constituents* of ordinary sewage could be oxidised at very high rates. He therefore advocated the removal of solids from sewage to a much higher degree than had been suggested previously as a preliminary to filtration. Further, he deduced that purification was to a great extent a function of the internal filter surface available. He was thus led to recommend the use of fine grade filters of depths approaching 12 feet, with a view to providing as large a surface of contact as possible. On filters of this type, Stoddart claimed to have purified well clarified liquids at rates of 700 to 1,400 gallons per cube yard.

At a later date, 1904, we have the advocacy of fine grade filters by Reid, and their construction at Hanley and other towns, but in most cases the depth did not much exceed 3 feet.

A reference may here be made to the filter designed by Ducat, who attempted to increase air circulation by constructing the filter walls of drain pipes placed horizontally. Realising that purification was retarded at low temperatures, he attempted to check the reduction due to increased ventilation by constructing perforated brick flues under the filter, and connecting them to a heating apparatus. Needless to say, such precautions have proved unnecessary. The names of Scott-Moncrieff and Whittaker are also associated with much valuable work in connection with the percolating filter.

Following Corbett's experiments with rotating distributors, there has been gradual improvement in design, but always with the object of distributing the sewage so that it percolates through the filter uniformly at a suitable rate in the form of a thin film over the surfaces of the material. So also, with regard to the design of filters, experience has led to proper care in the selection and grading of the material and the provision for ample aeration, so that there has now been developed an agent capable of purifying economically and satisfactorily all ordinary types of sewage and many others even of a complex nature.

Without discussing the several theories advanced with respect to the purification changes which occur in land filters, contact beds and percolating filters, it may be sufficient to state that in each case the action is essentially the same.

Each particle becomes coated with a gelatinous zoogleal film of organic matter in process of oxidation; the nidus of bacteria and higher organisms. By successive contact, the organic matter of the sewage is retained or absorbed on the gelatinous film. A purified effluent flows from the filter and the organic matter which has been retained gradually undergoes oxidation, chiefly by the agency of bacteria and higher forms of life.

HUMUS TANKS.

In the case of the percolating filter there is a gradual escape of the partially oxidised organic debris with the effluent. This spent organic matter resembles humus and, as it was found to undergo secondary

decomposition if allowed to settle and lie on the beds of streams, it became necessary to provide settling tanks for its removal from the effluent before discharge to the stream. These final settling tanks were termed "humus tanks."

PRELIMINARY PROCESSES—TANK TREATMENT.

The purification processes already referred to are those in which oxidation of organic matter is the fundamental principle involved, and all the efforts put forward have been with the object of intensifying the oxidation process. In the early stages of land treatment it was found that removal of the grosser solid matters from sewage led to increased volumes being treated upon a definite area, and accordingly measures were adopted for their removal. At first some form of screen for the removal of large floatingsolids was adopted, these screens, originally consisting of bars, sieves, or gratings, have in process of time developed into the various mechanical appliances now in use.

As a preliminary to land irrigation or filtration it soon became a practice to dig trenches or pits through which the sewage flowed before passing on to the land. These pits removed silt, grit and the larger particles of organic matter. When almost full they were filled in with soil and new pits excavated. Here we not only see the first stage of tank treatment, but also that of the disposal of sludge by trenching upon land.

Later, especially when chemical methods were to the fore, masonry tanks were constructed of ample size to remove nearly all the settleable solids. In cases where heavy chemical treatment had been applied for precipitating and recovering the manurial constituents of sewage, it was found impossible to dispose of the large quantities of sludge as had been anticipated, and the problem of its ultimate disposal became serious. A partial reaction from chemical precipitation, therefore set in, and that process became limited chiefly to sewages containing trade wastes. However, as the removal of suspended solids from sewage prior to filtration had been proved highly beneficial, tank treatment firmly established itself as a preliminary process and is still sound practice.

The design of tanks for effecting rapid and economical removal of solids has been the subject of numerous experiments.

SEPTIC TANK.

Difficulties of sludge disposal re-directed attention to the decomposition of organic matter as exhibited in putrefactive and similar processes. Scott-Moncrieff pointed out that sewage purification might take place in two stages, the first in which a partial liquefaction of the solid organic matter took place, and the second in which oxidation and nitrification occurred. He built plants to demonstrate this; the first portion of these consisted of a *closed tank* filled with stones, which he called the liquefying tank; the second part was made up of coke arranged in tiers

well ventilated, and upon which the effluent from the closed tank was oxidised. It was thought that the liquefication would proceed better in the absence of air, i.e., under anaerobic conditions. In 1895 Cameron developed the anaerobic process and designed a tank at Exeter which he patented as the "Septic Tank." This tank had a large capacity relative to the flow of sewage, and the influent and effluent pipes were carried down below the surface to prevent ingress of air. It was claimed that the liquefying organisms would break down the organic solids into simpler substances, some passing into solution and some escaping as gas. Many towns adopted the process in England, and although a considerable proportion of organic matter was destroyed, the claims for complete liquefaction proved incorrect, and the system did not contribute much towards the solution of the sludge difficulty. Further, septic tank effluents were generally dark offensive liquids, which when sprayed over land or filters produced a nuisance. Consequently, it was more general in practice to work them in conjunction with contact beds, especially as further sludge destruction was anticipated in the latter.

Modern opinion is mostly against anaerobic or septic action, it being generally held that rapid separation of the solid matter from sewage and the maintenance of aerobic conditions are far preferable as a preliminary to further purification.

TRAVIS HYDROLYTIC TANK.

In order to overcome difficulties connected with the septic tank and contact bed, Travis designed what he termed the "Hydrolytic Tank."

He concluded that clogging of contact beds was largely due to emulsified solids which were unsettleable in ordinary tanks; he wished to retain the liquefying action of the septic tank for the sludge, but at the same time to keep the effluent from the tank fresh.

To achieve these objects the tank was divided into three compartments. The two side chambers, through which the sewage flowed, communicated by slits in their sloping floors with the centre chamber, which extended below and under the side chambers. Sludge settling in the side chambers passed into the lower part of the centre chamber, there to undergo liquefaction, but in order to prevent undue accumulation of decomposition products and to supply fresh bacteria a proportion (about one-eighth) of the fresh sewage was allowed to flow through the middle chamber. In the two side chambers were a number of plates suspended almost vertically, the function of which was to collect the fine matter in suspension or emulsion and, when sufficient had accumulated, allow it to fall and pass into the liquefying compartment. The work of Travis is particularly notable by reason of his views upon sewage purification, based upon the working of the Hydrolytic Tank at Hampton, and which were widely discussed in 1908.

Travis claimed that sewage purification was largely a physical phenomenon, due to surface contact and desolution of organic matter.

IMHOFF TANK.

Imhoff (1909), designed a modified septic tank resembling that of Travis, with the exception that no plates were fixed in the settling chamber and no fresh sewage was allowed to flow through the sludge liquefying chamber, the latter being fitted with flues for discharging evolved gases to the atmosphere. This type of tank was eagerly adopted in America, where it almost became regarded as standard. It is stated, however, that practical results have fallen below expectations.

In this country there has been little inducement to adopt other than the ordinary single storey tank, many septic tanks have been converted to simple sedimentation or precipitation tanks, and separate sludge digestion along the Birmingham lines appears to offer much greater prospects of success than any hitherto achieved by the septic tank and its modifications.

RECENT DEVELOPMENTS; ACTIVATED SLUDGE PROCESS.

By 1914, standard practice for sewage purification in this country had almost settled down to the provision of sedimentation or precipitation tanks, percolating filters and humus tanks, and it is probable that this combination will continue to hold a prominent position for some time.

This practice had been arrived at, as will be evident from what has already been written, very largely by methods of trial and error, and much experience had been bought at a heavy price.

Scientific explanations had lagged behind innovations rather than given rise to them. It came, therefore, as a surprise when, early in 1914, Ardern and Lockett showed that purification could be effected without the aid of filters. Practice, in this instance, has followed upon careful research, with the result that sewage disposal as a science has been raised to a much higher level than formerly.

Ardern and Lockett, describing their researches, mention that many previous investigators, realising the part played by atmospheric oxygen in sewage purification, had tried the effect of passing a current of air through sewage liquids but had found purification too slow to be practicable.

In November, 1912, Dr. Fowler saw experiments in progress at the Lawrence Experiment Station, Massachusetts, in which air was blown through sewage in bottles, the insides of which had become coated with green algal growths. It was found that the purifying effect was greater in the presence of these growths. Acting upon Dr. Fowler's suggestion, Ardern and Lockett commenced similar experiments.

They passed air through sewage until complete nitrification ensued after five weeks. The clear settled liquid was then decanted, fresh sewage added, and aeration recommenced. The process was repeated a number of times and it was found that, as the deposit increased, the

time for each succeeding nitrification decreased until, by the time the deposit occupied one quarter of the bottle, six hours aeration with subsequent settlement yielded a liquid quite equal to that from efficient percolating filters.

The investigators termed the deposit "activated sludge," which is the name by which the process elaborated from their researches generally goes.

Essentially the process consists in bringing the sewage into intimate contact with the proper kind of organisms in the presence of excess of air. The activated sludge, produced as described, corresponds to and resembles the gelatinous film which coats the material of a percolating filter, but in the "activated sludge process" the film is maintained in circulation in the liquid in tanks instead of being supported upon a solid material over which the liquid trickles as in filters.

Following upon the practical application of the work of Ardern and Lockett, others, notably Haworth and Bolton, have succeeded in maintaining the conditions essential to success by circulating the mixture of activated sludge and sewage in specially designed tanks by mechanical agitators, relying on the solution of free air instead of injecting compressed air.

Mention should be made of a modification of the activated sludge process introduced by Watson and O'Shaughnessy at Birmingham. Here they have applied the process to the settled sewage as a preliminary aid to filtration upon percolating filters; by curtailing the period of aeration they aim at "flocculating" and removing the fine and immulsified solids and producing a liquid which can be filtered at an intensive rate. In the present stage of development it is impossible to say whether any one of the modifications now in use possesses advantages over the remainder, but it appears certain that future progress will be more dependent upon the extent to which the biological forces can be harnessed and intensified rather than to improvements in the mechanical equipment associated with the process.

In concluding this paper, although the remarks are somewhat scattered, most of the points referred to have at times greatly influenced the trend of sewage disposal methods, many have been in the past and still are, matters of controversy, the work of some investigators is gradually being forgotten, while that of others is re-attracting attention and investigation in the light of more modern conditions. We are still far from finality and much work remains to be done, but just as the use of large areas of land, and the crude and unsightly methods of applying sewage thereto, have been largely replaced by somewhat ponderous and costly artificial processes, so one may anticipate that these will eventually be replaced by compact and less costly plants scientifically designed and working under better control at a high degree of efficiency.

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Mr. W. J. Dibdin (Past President) in a written communication traced the successive developments in the purification of the Thames since he joined the Metropolitan Board of Works in 1876, eventuating in the precipitation of the solids by minimum doses of lime and iron and the barging of the sludge to deep water, and the introduction of bacteria beds and slate beds.

Dr. Odling, then Medical Officer for Camberwell, had already (in 1858) shown the importance of various organisms in the presence of dissolved oxygen in effecting the destruction of effete organic matter, and at a later date Dr. Sorby, the eminent microscopist, moored his yacht in the Thames and worked on the river organisms day and night.

Dr. Dupré, in a discussion at the Society of Arts in 1876, first gave public expression to the principle adopted in dealing with the Thames, viz., that sewage would be purified in future by treating the aerated sewage with living organisms.

Mr. Dibdin himself, in a paper read before the Institution of Civil Engineers in 1887, pointed out the essential difference between aeration and oxidation, and showed that the ultimate oxidation of the organic impurities was brought about by the life processes of various micro-organisms, and not by direct combination of the aerial oxygen dissolved in the water with the organic matters.

Various experiments in the aeration of London sewage were carried out at the Pimlico station in 1884; but it was considered that the cost of pumping either water or air for the purpose would be prohibitive. Pending the completion of the main drainage works, he (Mr. Dibdin) fell back upon deodorisation with permanganate of soda during the summer months. At first manganate of soda was purchased at £40 per ton and treated with sulphuric acid to form the permanganate. He then introduced the manufacture at Crossness of manganate, at a cost of £8 per ton, the total saving thus effected being upwards of £640,000.

In 1893 experiments in the biological filtration of sewage were carried out for the Board at Barking Creek by Mr. Santo Crimp, culminating in the formation of a filter one acre in extent to deal with 1,000,000 gallons per day. This bed was at first used continuously, with the result that it choked. Mr. Dibdin then gave it a three months' rest, and started it on the well known lines of filling, emptying and resting empty, with the happiest results. Beds worked on these lines were rapidly adopted all over the world, and were subsequently laid down by the Septic Tank Company in connection with Mr. Cameron's septic tank.

Similar beds, filled with coarse clinker, were subsequently installed at Barking Creek and at Sutton to deal with grit-settled sewage, the intention being to work them for a few years (say five) and then refill them with new material, putting the old clinker, etc. on one side to recuperate and reuse after purification by aeration. To obviate the chokage of the beds and allow the accumulated debris to escape, and with the further object of increasing the working capacity of the beds from about 30 per cent. to 60 or 70, he introduced the Slate Bed System, in which the lumps of clinker were replaced by layers of slate.

Beds so made were to all intents and purposes indestructible, and after working successfully for over twenty years were in as good a condition as when they were first started. The effluent, which showed a purification (in addition to the removal of the sludge) to the extent of 50 per cent. or more, was further treated in contact or sprinkler beds or on land, or in some cases passed direct into a river or into the sea.

The "sludge," or residue, or "humus," as it might be termed, was caught in ash settling drainage beds, or even on the surface of the fine beds, from which it was removed from time to time by means of a shovel. On exposure to the air it dried up without nuisance or smell into a fine black mould of good manurial quality, which in the opinion of Mr. Barr, the well-known seedsman, was beneficial to plants even of a delicate kind. The cost of this system at Faversham, per million gallons of sewage treated, varied even during the war time, in the years 1914 to 1920, from 22s. 3d. to 38s. 7d. Mr. Andrews, the Town Surveyor, said, "In my opinion the working of the system has been an unqualified success and I am glad that my Council decided to install it."

Mr. Garner might be interested to learn that he (Mr. Dibdin) was the first to advocate the appointment of trained chemists in charge of sewage works.

DISPOSAL OF INDUSTRIAL WASTES IN THE UNITED STATES.

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Stream pollution by industrial wastes, in England commonly called "trade wastes," has assumed increasing importance during the last fifty years, coincident with rapid industrial development. Conditions vary greatly, due to diversity of volume and quality of wastes and to differences in relative volumes of available diluting water.

EFFECT OF INDUSTRIAL WASTES UPON NATURAL WATERS.

The effect of many wastes upon waters into which they are discharged is similar to that of sewage, causing discolouration, turbidity, stimulation of fungal and algal growths, depletion of dissolved oxygen, extermination of fish life, putrefaction accompanied by objectionable odours, and deposits affecting navigation.

Unlike sewage, certain industrial wastes contain constituents sufficiently toxic directly to destroy fish life, while others, like acid mine waters, phenol wastes from gas plants and saline wastes from salt works and oil wells, render proper purification of waters for domestic use difficult and in some cases impracticable. Most wastes, indeed, tend to increase the burden placed on plants for the purification of water for domestic uses.

Streams carrying tannery wastes may convey anthrax bacilli to large areas of grasslands, thus endangering cattle grazing thereon ; relatively small quantities of glue factory wastes have caused excessive foaming of waters of large rivers, seriously interfering with their use for recreation ; while waters have been rendered unsatisfactory for irrigation of crops, by the wastes from mines and ore refineries.

CLASSIFICATION OF WASTES.

Industrial wastes may be grouped into three main classes—animal, vegetable and mineral, according to the nature and origin of their predominant ingredients. This grouping indicates roughly the relative rapidity of putrefaction.

Some of the more common wastes are :—

Wastes of Animal Origin, from

Dairies.
Fertiliser industry (also mineral).
Glue industry.
Leather board industry.
Packing houses.
Soap industry (also vegetable).
Tanneries.
Wool scouring plants.
Woollen textile mills.

Wastes of Vegetable Origin, from

Beet sugar industry.
Canning industry.
Corn products industry.
Cotton textile mills.
Distilleries.
Paper industry.
Pulp industry.
Rubber industry.
Saw mills.
Straw board industry.
Wood distillation industry.

Wastes of Mineral Origin, from

Bleacheries.
Chemical industry.
Dye works.
Gas plants.
Metal industry.
Mines (coal mine drainage, coal washing, etc.).
Munitions factories.
Oil refineries.
Oil wells.
Salt works.
Water purification plants.

Wastes are often mixtures of materials of more than one class. For example, tannery wastes may contain animal fleshings, bark extractives and spent lime.

EFFECT OF INDUSTRIAL WASTES UPON MUNICIPAL SEWAGE.

The influence of wastes upon the character of sewage depends upon two principal factors :—

The relative volumes of wastes and sewage.
The composition of the wastes.

The great increase in weight of sewage constituents due to wastes, is illustrated by the following rough estimates :—

City.	Suspended solids *per capita*	Oxygen consumed per cent.
Akron—rubber reclaiming plant wastes	120	140
Chicago—Packing house district only —packing house wastes	460	225
Dayton—paper mill wastes.. ..	60	25
Fort Worth—packing house wastes	65	—
Gloversville—tannery wastes ..	155	115
Milwaukee—portion only of city, packing house and tannery wastes	70	10

Thus it is seen that the discharge of wastes into the sewers was equivalent to increasing the population in these cities from 60 to 460 per cent., or from 10 to 225 per cent., as measured by the suspended solids and oxygen consumed, respectively.

Such increments of wastes add greatly to the cost of treating sewage, by increasing the load upon the plants. Moreover, some wastes, such as acid pickling liquors, are detrimental to biological action and may necessitate modification in plant and processes, otherwise suitable for sewage.

Occasionally, however, wastes may be utilised to advantage, as at Worcester, where the quantity of iron sulphate from pickling liquors has at times been sufficient to cause excellent chemical precipitation with addition of lime.

Large quantities of heavy oils from industries and garages have formed troublesome scum in channels and tanks. In one town wool scouring liquors made treatment of the sewage upon intermittent filters impracticable, owing to clogging of the sand. At Atlanta carbide plant wastes caused a thick scum to form on the surface of the sedimentation compartments of Imhoff tanks.

Some cities have required partial treatment of wastes before their discharge into sewers, as at tanneries, where tanks and screens have been installed for removal of suspended solids.

Many cities have ordinances prohibiting the discharge of substances which shall injure sewers and other structures or interfere with the treatment of sewage, but they have not generally been enforced.

Treatment of wastes has generally been demanded to prevent :—

- Contamination of domestic water supplies.
- Damages to commercial fisheries, particularly contamination of shellfish.
- Annoyance due to offensive odours.
- Pollution of waters used for industrial processes.
- Infection of cattle and pollution of their water supplies.
- Pollution of streams to an extent which would interfere with their use for recreation—fishing, boating, bathing and camping.

TREATMENT OF INDUSTRIAL WASTES.

The methods commonly used for the treatment of sewage are applicable to the treatment of many wastes. With others special adaptations of existing methods must be made, or new methods developed.

Plain sedimentation and chemical precipitation are both in use for the treatment of wastes containing large quantities of suspended solids. Ordinary settling tanks are commonly employed, although there is a tendency toward increase in the use of tanks equipped with mechanical devices for the continuous removal of sludge.

Where it is desirable to remove a greater proportion of the suspended and colloidal matter than is possible by plain sedimentation, chemical precipitation with alum, and lime where necessary, is commonly employed. This treatment is particularly well adapted to certain tannery and paper mill wastes, and it has been found in some instances that control of the hydrogen-ion concentration assists materially in efficiency and economy of operation.

Where a still greater degree of purification is required, intermittent filters are employed and have been found to be capable of efficiently purifying settled tannery, glue works and paper mill wastes. Trickling filters also have been used successfully with tannery wastes.

The activated sludge process has been used experimentally and upon a comparatively large scale, and has been found capable of successfully purifying certain tannery, packing house and beet sugar wastes.

The acid cracking process has been used for many years with success, in removing a large proportion of the grease from wool scouring liquors. The acid effluent, however, usually requires further treatment to fulfil local requirements.

In a number of cases chlorine has been employed for disinfecting the wastes from tanneries using hides likely to be infected with anthrax.

Artificial dilution with water drawn from storage reservoirs is sometimes successfully employed, in order to reduce the extent of treatment which would otherwise be necessary.

In one case sodium nitrate has been introduced into the treated wastes before their discharge, for the purpose of maintaining a suitable supply of available oxygen in the river at times of extreme low flow.

Another important problem is the disposal of the sludge produced by tank treatment of wastes. Recovery and utilisation of the suspended cellulose fibres in the sludge from paper mill and rubber reclaiming plant wastes has been accomplished in a few instances. While de-watering of sludge has been achieved experimentally by filter presses, centrifuges and vacuum filters, the use of porous beds of sand or cinders for this purpose has generally been found more economical. Disposal of the de-watered sludge is then accomplished by filling low ground, or in the case of sludges from certain industries, by use locally as fertiliser.

GOVERNMENT CONTROL.

Massachusetts was one of the earliest states to take cognizance of stream pollution. In 1875, the Legislature passed an act requiring the State Board of Health to investigate and report upon the subject. Following other investigations and reports the State Board of Health, in 1886, was given jurisdiction in this matter and in 1888 established the Lawrence Experiment Station for the purpose of investigating the purification of sewage and wastes. The investigations at this station have continued for thirty-six years and have contributed information of great value, particularly in establishing the principles underlying the action of natural agencies in polluted waters and the several processes of treatment of sewage and wastes.

In general, the control of steam pollution is under the jurisdiction of state departments of health, whose powers, however, are often seriously limited. In certain states, pollution affecting fish life is under the control of conservation commissions, or fish and game bureaus. Other states have created special boards, such as the Board of Purification of Waters established in Rhode Island in 1920. In 1923 Pennsylvania made provision for a Sanitary Water Board, comprising the Secretary of Health, the Secretary of Forests and Waters, the Attorney-General, the Commissioner of Fisheries and the Chairman of the Public Service Commission. This Board exercises the authority relative to stream pollution, formerly vested in several boards.

The Public Health Service of the Federal Government may investigate the pollution of streams but has no authority for administrative control. It has made numerous investigations upon the treatment of industrial wastes. Other branches of the Federal Government, such as the departments of War, Commerce and the Interior, are interested in one or more aspects of stream pollution. In the case of New York harbour the Federal control of pollution is vested in the Supervisor of the Port, a naval officer.

Groups of municipalities have carried out joint projects administered by commissions. Among these are the Metropolitan District Commission of Massachusetts, the Trustees of the Sanitary District of Chicago and the Passaic Valley Sewerage Commission of New Jersey. Primarily they deal with sewage, but industrial wastes often materially influence their problems. These commissions while somewhat similar to the rivers commissions of England, do not generally have as extensive judicial and police powers. In comparatively few cases have they had jurisdiction over entire drainage basins.

An International Joint Commission, established by the governments of the United States and the Dominion of Canada, has investigated the pollution of the Great Lakes and the St. Lawrence River.

The Congress has authorised the President to call a conference of maritime nations with a view to the adoption of effective means for preventing pollution of navigable waters by refuse oil. The problem is being studied and a conference probably will soon be called.

RATIONAL REGULATION OF WASTES TREATMENT.

Typical of special rivers legislation is the Neponset River Act, Massachusetts, which prohibits the discharge of sewage or of "any other substance which may be injurious to the public health or may tend to create a public nuisance, or to obstruct the flow of water, including all wastes or refuse from any factory . . ., unless the owner thereof shall use the best practicable and reasonably available means to render such wastes or refuse harmless."

This Act distinguishes between sewage which is absolutely prohibited and industrial wastes which are excluded, subject to some qualifications. The Act is open to interpretation, however, which does not recognise sound principles of control of stream pollution.

Such fundamental principles were stated in 1916 by a committee of the Sanitary Engineering Section of the American Public Health Associations, as follows :—

(*a*) " . . . It is possible theoretically, though not always practicable, by either or both of these processes (sewage and water purification) to carry purification to almost any desired degree."

(*b*) " . . . The discharge of sewage and wastes into such waters* must be expected, as a natural and, under proper restrictions, a suitable method of disposal . . . "

(*c*) " The method of disposal, termed 'dilution,' constitutes a valuable sanitary and economic resource or asset to communities and industrial establishments . . . "

(*d*) " With the natural growth of population and industries throughout the country, it is impracticable to maintain our streams in their original state of purity, and all municipalities taking water supplies from water flowing off from populated drainage areas must for the proper protection of public health provide themselves with water purification plants irrespective of the methods employed for sewage disposal."

(*e*) " The requirements and share of responsibilities to be met by various municipalities, corporations and persons in regard to treatment of sewage and other wastes, purification of water and use of bodies of water, involve not only sanitary but economic and legal considerations, the jurisdiction and administration of which should be left to the proper authorities."

There has been a tendency toward strict prohibition of introduction of sewage and industrial wastes into streams without a high degree of prior purification. Such action tends to delay progress in securing reasonable control of pollution. An excellent illustration of such control is afforded by the operations of a large sheepskin tannery and wool scouring plant situated on a comparatively small river.

This plant provides for degreasing the wool scouring liquors and treating highly polluted wastes by coarse screening, plain sedimentation, chemical precipitation, intermittent filtration and dilution.

*Running streams and other bodies of water.

The operation of all features of this plant at maximum practicable efficiency during all seasons of the year, would require an exceedingly large expenditure for results unnecessarily refined. The plant is therefore so operated as to provide only such degree of purification and dilution as is necessary to prevent the formation of deposits, gross discolouration, high turbidity and putrefactive conditions along the river.

Treatment is subject to seasonal regulation. At times of *extreme high river and low temperature*, the tannery and scouring wastes are simply screened and settled. With an *ordinary high river and low temperature*, the scouring liquors are degreased prior to admixture with the tannery wastes. When the *river flow and temperature are moderate*, the wastes from the sedimentation tanks are diluted with an appropriate measured volume of water from a large storage reservoir. When the *river is low and the temperature is high*, about one-half the settled wastes are diluted before discharge, and the remainder subjected to chemical precipitation followed by intermittent filtration—a stable effluent being produced. During a few short periods of *extreme drought in warm weather*, sodium nitrate has been added to the final effluent to provide a supply of oxygen. At *all times* a portion of the wastes which are only very slightly polluted, is discharged directly into the river without treatment.

The regulation of the treatment is under the supervision of a chemist who devotes his entire attention to this work and who is aided in the exercise of judgment by weekly inspections and analyses of river water for several miles below the tannery.

The magnitude of the problem of industrial wastes disposal is realised by few engineers, manufacturers and legislators. There are many single industries the polluting properties of whose wastes are equivalent to those of the domestic sewage from a city of 100,000 persons, and some of the wastes are far more expensive to treat than the sewage from an equivalent population. It is therefore of the utmost importance that the laws be administered with due regard for the "rule-of-reason," that treatment be regulated according to the actual needs in each case, and that treatment plants be designed and operated with a keen appreciation of cost on the one hand and the accomplishment of the requisite results, on the other.

PURIFICATION OF TRADE WASTE WATERS IN HOLLAND.

(*Abridged*).

By H. Kessener,

Director of the Dutch Government Institute for the Purification of Waste Waters.

The pollution of the canals in Holland by trade wastes has gradually increased to a very high degree. The agricultural industries, sugar, dairy, strawboard and potato-flour factories, far from the towns have been largely responsible for the nuisances caused, and many difficulties have arisen with the authorities.

The province of Groningen is in bad repute on account of its evil-smelling canals. The conditions became there so intolerable that the Government appointed a commission in 1908 to investigate means of efficient improvement. I was entrusted with the carrying out of the experiments.

In the report of 1912 practical methods for the purification of the waste waters of strawboard and potato-flour mills were suggested. In 1911 I found a method for the disposal of the sugar-factory waste, and in 1913 I built the first satisfactory working biological filter for a dairy.

As the results obtained have not been published in any language except Dutch, it appears to me of use to tell something about these experiments.

The composition of these wastes is very divergent on account of the different origin and manufacture, although in all of them the class of carbohydrates is represented to a very high extent. Besides this, a large quantity of proteids is to be found in the waste waters of the potato-flour and dairy industries which are practically absent in the wastes of sugar and strawboard mills. Finally, a large amount of fibre is in suspension in the waste water of the strawboard industry and of grease in the dairies.

DAIRY WASTE.

Efficient purification of these waste waters is possible by irrigation and is often adopted in sandy districts. Where the soil is not suitable for irrigation, the application of biological treatment is advised. The combination of septic tanks and percolating filters has given excellent results.

In 1913 I built a plant for a dairy dealing with seven million litres of milk a year and discharging 24 cubic metres of waste water a day.

This plant has given every satisfaction and no trouble whatever since it was constructed 11 years ago. A description is given in Mr. v. Ysselsteyn's paper on pp. 321–242.

The results are given in Table I.

TABLE No. I.

Parts per 1,000,000.

	Septic tank.		Effluent percolating filter when treating.	
	Influent.	Effluent.	13 m³. per day.	24 m³. per day.
Total Solids	4140	2650	—	—
Solids in solution { total.. ..	3615	2485	1712	1865
Solids in solution { ash	1765	1595	1525	1565
Solids in suspension { total.. ..	525	165	—	—
Solids in suspension { ash	275	105	—	—
Total Nitrogen in solution	140	135	24.5	39
Total Nitrogen in suspension ..	43	45	—	—
Free and saline ammonia	52.5	94	11	24
Albuminoid ammonia	24	22	3.8	9
Nitrites	0	—	2	5
Nitrates	0	0	40.5	12.5
Permanganate figure 3 minutes test before } 7 days incubation at 30° C.	232	192	7	38
Permanganate figure 3 minutes test after } 7 days incubation at 30° C.	—	—	15	69
Permanganate figure 4 hours test ..	720	424	38	85
Permanganate figure in alkaline solution	1334	717	106	195
Permanganate figure in acid solution	2474	1121	119	231
Chlorine	571	565	565	565

The rapid development of the activated sludge system led us to make investigations for purifying these wastes along that line.

After a series of preliminary experiments our Institute put down at Vorden in 1922 a Bolton tank (surface-aeration), and treated with it the effluent from the septic tank. Although the purification was good, the practical results were not very promising, as bulking occurred, and gave so much trouble that we had to stop after some months. Under-aeration was the reason of the failure.

Better results were obtained with a small Haworth tank operated on the fill-and-draw principle, and treating milk in a dilution of 1 : 100. It took, however, a long time (16 hours) for sufficient aeration.

As a consequence of the results obtained a number of co-operative dairies lent us their financial assistance, voting fl. 10,000--(about £825) for further experiments, which are still being carried on.

An old septic tank, 4m. long, 3m. wide and 2m. deep divided into two sections was converted into an aeration-tank (air-blowing system), which is operated on the fill-and-draw principle. In one of those sections the crude liquid is treated, in the other the effluent of the septic tank. Another part of the crude water is pumped into a storage tank, and is treated in the Bolton tank and the rest on the existing percolating filter.

The results obtained so far with 10 hours aeration of the crude waste and 25 per cent. activated sludge are excellent.

When a part of the supernatant liquid is allowed to flow away and the rest of the purified water is mixed with an equal amount of crude waste water, the results obtained are given in Table II.

TABLE No. II.

Parts per 1,000,000

		Oxygen absorbed 4 hours test.	Free and saline ammonia.	Albuminoid ammonia.	Nitrites.	Nitrates.	Methylene blue-test.	Chlorine.
A Mixture of crude waste with the liquid from the previous treatment	When 60% of the supernatant liquid has been drawn off.	232.6	30.5	2.2	1.3	absent	decoloured within 30 minutes	276
B Liquid A after 5 hours aeration (slightly turbid)		4.8	0.2	0.9	0.04	absent	decoloured in 24 hours	
C Liquid A after 10 hours aeration (absolutely clear and odourless)		3.8	0.2	0.3	absent	absent	not decoloured in 4 × 24 hours	
D Liquid A after 22 hours aeration		3.8	0.2	0.3	absent	absent	not decoloured in 4 × 24 hours	
E Mixture of Crude waste water with liquid D.	When 80% of the supernatant liquid has been drawn off.	248.3	53.4	3.9	1.6	absent	decoloured within 20 minutes	270
F Liquid E after 6½ hours aeration (Slightly turbid)		9.2	1.6	0.95	0.8	trace	not decoloured within 4 × 24 hours	
G Liquid E after 9½ hours aeration (Slightly turbid)		4.1	0.3	0.65	absent	absent	not decoloured within 4 × 24 hours	
H Liquid E after 12 hours aeration (completely clear)		3.5	0.25	0.45	absent	absent	not decoloured within 4 × 24 hours	
I Liquid E after 21 hours aeration (completely clear)		3.5	0.25	0.45	absent	absent	not decoloured red within 4 × 24 hours	

A peculiarity is, that the liquids treated with the activated sludge contain no nitrites and nitrates or traces only as contrasted with the effluent of the percolating filter.

SUGAR FACTORIES.

As is well known, sugar factories discharge two kinds of waste waters, viz. *a* From the washing of the beets (from the flumes and washing-machine) amounting to from 8 to 22 times the weight of the beets treated. *b* From the manufacture of sugar (water from the diffusion-battery and from the pulp presses), amounting to from $1\frac{1}{3}$ to double the weight of the beets, or from 6 to 16 per cent. of the total quantity of the waste water.

The following list shows that the nature of the two kinds of water is very different.

TABLE No. III.

Parts per 1,000,000.

Waste Water from the:	Solids in suspension.			Solids in solution.			Permanganate.				Organic nitrogen.			Free and saline ammonia.
	Total Amount.	Organic. Amount.	Organic. in % of total.	Total Amount.	Organic. Amount.	Organic. in % of total.	3 min.	4 hours.	in alkaline solution.	in acid solution.	Total.	in suspension.	in solution.	
Diffusion battery..	1080	825	**76.4**	1732	1015	**58.9**	152	676	2518	3350	104	34	70	6.5
Pulp presses .	2370	2110	**89**	3059	2370	**77.45**	392	1520	5025	8652	115.5	41	74.5	24.0
Flumes ..	6150	650	**10.5**	1146	418	**36.5**	70	195	1065	682	55	16.5	38.5	6.7
Washing machines	8680	1150	**13.25**	2063	682	**33.1**	99	275	1397	1198	77	37.5	39.5	5.2

The water *a* contains more inorganic grit and humus, while the water *b* is more of an organic character (pulp-cells and sugar).

a Waste waters from the washing of the beets.

It was found that when the tails, trash, fibres, leaves, etc., are removed by a catcher, and the sand and clay by a series of sedimentation tanks, operated intermittently, the effluent generally can be discharged into the canals, provided that every settling tank is used only during a shorter time than the time of incubation for putrefaction or cellulose-fermentation.

Washing with cold water should, therefore, be applied or the hot water of the condensers should be cooled before using it in the flumes.

When using fresh water for the washing machine, amounting to about 10 per cent. of the total quantity of the mixture, 90 per cent. of the effluent of the settling tanks can be reused in the flumes.

The separation of sand and clay from the leaves, trash, etc., in one stage is difficult. I constructed a trash-catcher, which has given every satisfaction, and from which the trash is removed automatically.

By this catcher a quantity of trash, etc., amounting to ½ per cent. of the weight of the beets, is removed, and transported by a worm to the pulp which is carried away by the farmers. A sugar factory at Groningen dealing with 3,300 tons beets per day, with a water consumption of 25 m^3 per minute, removes 16 cubic metres trash and tails per day.

b Waste water of the pulp-presses and the diffusion-battery.

In 1911 I made experiments with the purification of these wastes in connection with investigations in the biological treatment of the waste water of potato-flour mills.

The organic matter of the latter consists of about 40 per cent. of carbohydrates, and it was found that if an acid fermentation had started the purification by a percolating filter was greatly hindered.

As the pulpwater becomes very readily acid a preliminary treatment was indispensable.

After mixing the pulp water with lime till an alkaline reaction was obtained, and a subsequent sedimentation, the resulting liquid was treated in a septic tank in which an intensive methane fermentation is proceeding. A part of the organic matter escapes as carbon-dioxide and methane, a part of the nitrogenous matter is converted into ammonia, which is more easily nitrified than the proteins of the beets.

The average results which were obtained are shown in Table IV.

TABLE No. IV.

Parts per 1,000,000.

	Crude liquid.	Effl. septic tank.	Effl. percolating filter.
Total solids	3500	2170	1960
Ash	1390	1760	1640
Loss on ignition	2110	410	320
Permanganate 3 minutes	250	98	25
,, (in alkaline solution)..	4300	376	146
,, (in acid solution) ..	5800	436	146
Organic nitrogen	62	21	6
Free and saline ammonia	28	68	9
Nitrites	0	0	1.5
Nitrates	0	0	48

If the fine pulp-cells from the waste water were carefully removed before, and a three days' septic tank treatment was allowed, 1 cubic metre could be purified by 2 cubic metres of filtering material per day.

Instead of treating the waste water with lime, a part of the lime-mud from the filter-presses can also be used. The addition of this gives a complete clarification.

The clarified liquid contains more organic matter in solution than the original waste water but it is limpid and slightly alkaline and can be purified biologically much better. On a percolating filter it can be put direct or after having been brought first in a fermentation tank.

In 1922 we constructed a percolating filter at a sugar-factory on which we proposed to treat 1 cubic metre water per square metre per day. The preliminary treatment consists only of a short settling in Dortmund-tanks.

Instead of purifying these waste waters reuse is also possible. Professor Söhngen and I found that when the pulp water was mixed with lime-mud a coagulation took place and a liquid of constant alkalinity resulted. When treating this with a small quantity of carbon-dioxide it became suitable for use instead of clean water, the sugar from it being in this way utilised.

At some factories in Holland the waste water is thus clarified and re-used in the battery for making juice or for emptying a diffuser, also for sweetening off the juice filter-presses, for cleaning the measuring-tanks, etc. If all the waste water cannot be reused, the rest can be purified biologically, as described above.

Since 1920 we have made experiments with activated sludge for the treatment of these wastes. A very careful removal of the finely divided pulp proved to be necessary and fifteen hours of aeration is required. If clarified before with lime-mud, thirteen to fourteen hours is sufficient.

STRAWBOARD WASTE.

Straw is boiled with lime and steam under pressure in rotating boilers, and the resulting substance is afterwards ground in so-called "hollanders" and conveyed to the paper-machines, from which the waste waters run away.

From 1·35 tons of straw, one ton of strawboard is obtained. Consequently a very large quantity of polluting substances flow away with the waste water, amounting to thirty cubic metres per ton of pasteboard.

A part of the organic matter is in solution (about six parts per million); another part (fibres : about two parts per million) is in suspension.

The solids in suspension do not settle in the sterile liquid under ordinary conditions, but only by bacterial precipitation in the fermentation tank.

A treatment by a Füllnerfilter does not give satisfactory results, nor does a Jewellfilter. We tred the treatment with clay, suggested by Rohland, but it proved to be unsatisfactory and too expensive. The same is the case with chemical precipitation. The best precipitant is superphosphate (Sjollema), of which 0.45 per cent. should be used to get a clear effluent. This, however, still contains a large quantity of organic substances in solution, causing putrefaction in the canals.

If brought into a fermentation tank the high alkalinity of the crude liquid disappears immediately by the carbon-dioxide formed, and a rapid decomposition takes place, producing methane and carbon-dioxide.

In 1909 I built an experimental percolating filter, filled partly with cinders and partly with peat.

The results obtained when treating the effluent of a fermentation tank were very satisfactory (see Table V.)

TABLE No. V.

Parts per 1,000,000.

	Crude waste water.	Effl. septic tank.	Effluent percolating filter.
Total solids	12340	7800	2150
Loss on ignition	7040	1260	456
Ammonia	11	3	0.3
Albuminoid ammonia	5	4	—
Total Nitrogen	96	58	18
Permanganate: 3 minutes test	—	—	140
Permanganate: 4 hours test	4830	1520	285
Permanganate: 10 minutes boiling	9630	2430	460
Nitrite	—	—	trace
Nitrate	—	—	trace
Total calcium	2040	1260	180
P_2O_5	68	—	—
K_2O	208	—	—

Since 1909 I have been experimenting in order to obtain the maximum yield of gas from a fermentation tank. At a temperature of 31° C. in a tank 20 metres wide and 200 metres long it was found that vigorous fermentation was mainly restricted to the first 20 metres and gave 0.2 cubic metres of gas per square metre per hour or 120 cubic metres per hour from the first 30 metres of the length of the tank. The calorific value is about 7000 calories. The composition varied from 23 to 30 per cent. carbon-dioxide and 70 to 77 per cent. of methane. This methane is produced both by fermentation of the cellulose and by the fermentation of the dissolved organic matters, e.g., the xylane, of which about 1 gramme per litre is present. It can be precipitated by alcohol from the waste water after clarification and neutralised by superphosphate and decolorised by animal charcoal. A strawboard mill at Sappemeer drove a gas-motor of 140 h.p. by the gas of the tanks, utilising it afterwards by burning it under the boilers. Part was delivered to the local gas-works by contract.

[The complete paper, with many illustrations, may be obtained from the author.]

PURIFICATION OF DAIRY TRADE WASTE WATERS.
(*Abridged*).

By H. A. Van Ysselsteyn,

Director-General of Labour.

The question how effectively to purify the waste water of dairies is of the greatest consequence to Holland. Such dairies are being built all over the country, it, and often in places where it is extremely difficult to give the factory waste water a suitable outlet, which therefore often infects the surrounding district in the most obnoxious manner.

Several factories have tried the purification by building septic tanks; but in most cases these arrangements have rather an unfavourable influence on the nuisance done to their vicinity.

If the dairy happens to be near some river of sufficient power, with a strong current, it will generally prove advantageous to lead the waste water directly into it. After being distributed by the current, it will finally be made inoffensive by the self-purifying power of the water.

If it is conveyed to a septic tank first, and afterwards led off in a putrefying and stinking condition to some slow or stagnant water, the latter will be locally more polluted than if the waste water had never passed the septic tank. Efficient purification can only be effected, either by conducting the waste water, after it has left the septic tank, to oxidation beds, which purify it biologically, or by irrigation.

The last-mentioned procedure is only applicable in places where the soil lends itself to it, particularly in sandy tracts, and the land is cheaply to be procured.

The purification of waste water by means of a biological filter was for the first time applied in Holland at Fynaard (North Brabant). At a co-operative steam-dairy, established in 1903, a septic tank with three oxidation beds was built in 1905.

The system of contact beds was first adopted, involving, especially for smaller factories, the great disadvantage that their efficiency depends on their comparatively difficult attendance.

Another disadvantage lies in the fact that the waste water of a dairy is mostly produced in the morning. Now it is absolutely necessary for the good working of a septic tank that the water flows through it as regularly as possible: it follows that it is advisable to place a reservoir before the septic tank.

PURIFICATION WORKS FOR WASTE WATER FROM DAIRIES.

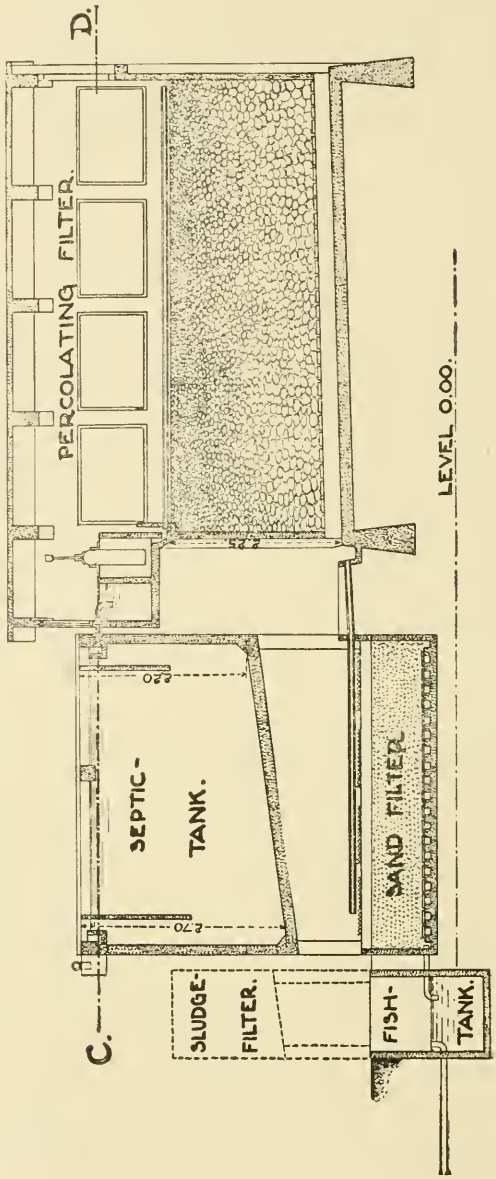


FIG. 1.—Vertical Section on A. B.

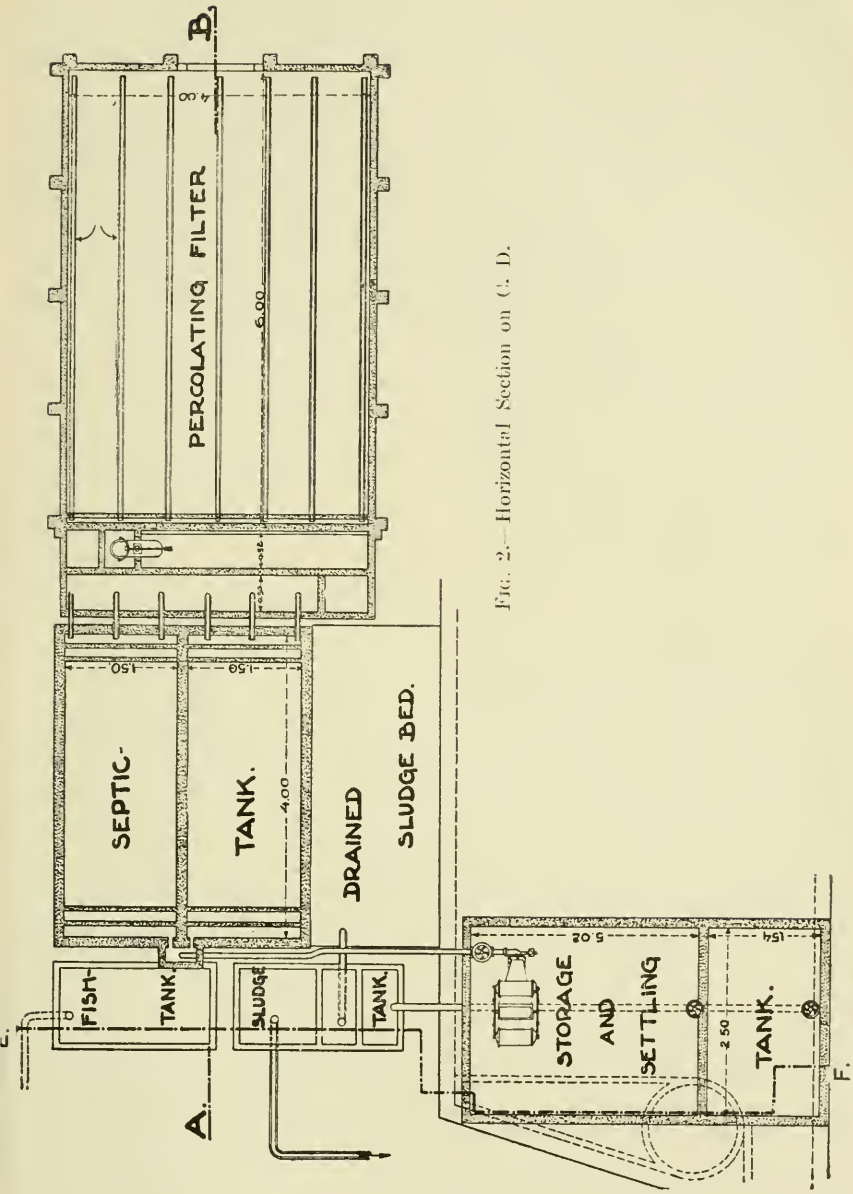


FIG. 2.—Horizontal Section on C. D.

The water which leaves the above installation is neither scentless nor colourless.

Such is indeed the case with the plant built in 1913 at the dairy in Vorden. This factory deals with 17,000 to 47,000 litres a day and 7 million litres a year.

Owing to a communication in the "Centraal Verslag der Arbeidsinspectie" (Central Report of the Labour Inspection) concerning the project of a slaughtering-house, the co-operative dairy consulted the undersigned and asked him for advice. He was inclined to draw up a plan in the course of his service, if the board in question would consent to consider themselves bound to carry out all the directions which might be given by him, and moreover would consent to suffer all the experiments to be made with the purification plant in view, that might be thought desirable by the service of the Labour Inspection.

The factory of preserved meat (the firm of Poessebosch) near the above dairy, made a similar request, which was granted on the same conditions. About this, details are given later on.

The plant of the dairy Figs. 1, 2, and 3, was intended for the purification of 11 m^3 of waste-water a day, according to the plans of Mr. Kessener, chemical engineer to the Labour Inspection. The quantity named was given by the factory, but in reality much more water was produced by the same.

The water actually discharged consists of :

(*a*) The rinsing-water of the milk-pots and different apparatus.

(*b*) The wash-water of the churns.

In this, the condensation-water of the machine and the cooling-water are not taken into account, the latter according to its nature is allowed to run off untreated.

After running through some pits where the coarse impurities settle and which must be cleaned from time to time, the two kinds of waste water are conveyed to the dirty water tank, to which lime water is added. The quantity of this has to be fixed in such a manner that the acid reaction of the waste water is changed into an alkaline one.

The mixture of waste water and lime water is pumped into a storage and settling tank having a capacity of 23 m^3. From this the water flows away by means of a floating arm, so as to be always decanted just beneath the surface. As, of course, there must always remain some water in the tank, it can be considered as having an efficient capacity of 20 m^3.

The action of the lime produces a flocculent precipitate, consisting of carbonate of lime and a small quantity of proteids. This precipitate carries off the fat too, which is of great importance, as otherwise it would lead to the clogging of the percolating filter mentioned below.

The bottom of the reservoir has a fairly steep slope. At its lowest point there are two sludge valves through which the precipitate can be let off into a sludge tank with a capacity of 2 m^3. From this tank the sludge is conveyed to $6\frac{1}{2}$ m^2 sandy soil, which is properly drained

The draining water runs off to the dirty water tank already mentioned, and together with the waste water of the factory it is pumped up and purified. The sludge remaining behind on the soil dries there, is odourless and can easily be removed.

From the reservoir the water flows as described above to a septic tank, divided into two sections, each having a capacity of 13 m^3. This tank is supplied with inlets and outlets and with vertical scumboards, by which the water is forced down to flow over the sludge where the bacteria live causing the biological action.

In order to secure a proper destruction of the organic matter, efficient ferments are added from another fermentation tank.

The water purified so far, flows to a percolating filter, 6 m. long, 4 m. broad, and 2m. high. This filter consists of lava piled up according to its size. The lower layer comprises pieces of 7 to 12 cm., the upper of 6 to 10 mm. The lowermost layer rests on perforated tiles, covering small channels running all over the bottom of the filter. These channels run into an open water-gutter on one side of the filter bottom.

The distribution of the water on the filter is performed after the method of Calmette, through iron pipes, perforated at an angle of 45°, spreading the water intermittently over the filter by small jets. By means of an automatic apparatus the duration of the spreading as well as that of the intervals, can be regulated at will. It has now been so arranged that the sprinkling lasts one minute, and is followed by a seven minutes' interval.

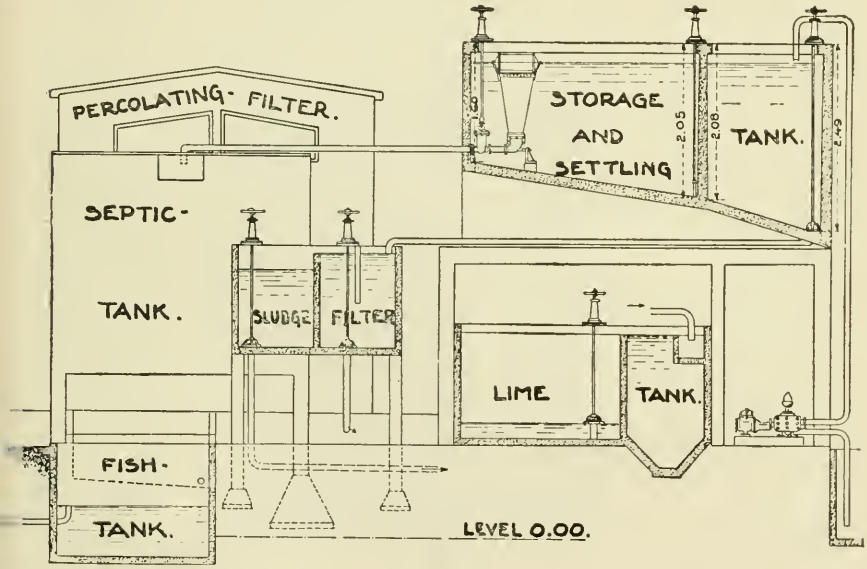


Fig. 3.—Vertical Section on E. F.

PURIFICATION WORKS FOR WASTE WATER FROM MEAT PRODUCTS FACTORY

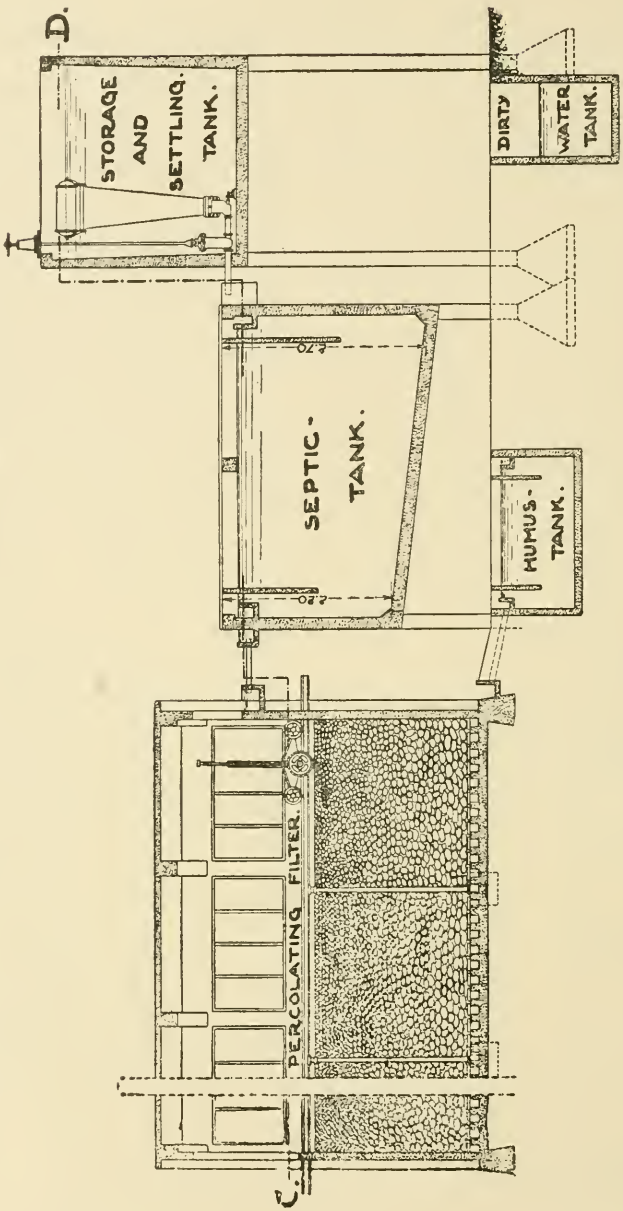


FIG. 4.—Vertical Section on A. B.

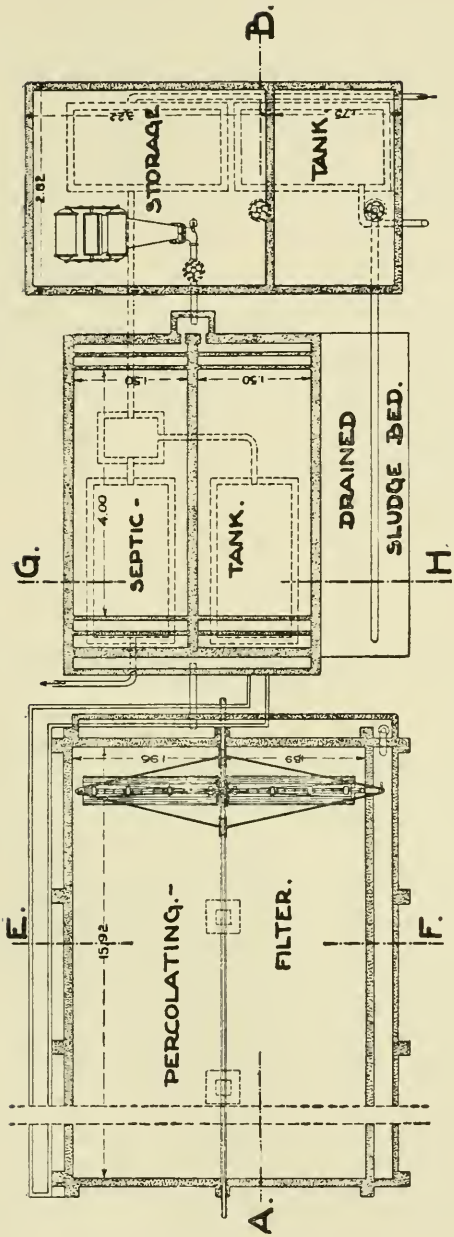


FIG. 5.—Horizontal Section on C. D.

When the water has left the filter, it is again conveyed to another filter of fine cinders, having an area of 7 m^2. This serves to hold back the suspended impurities brought along with the effluent of the percolating filter. The water flows on to this filter through a distributing apparatus according to Stoddart's dripping-system.

The whole construction is made of reinforced concrete. The percolating filter is covered all over with a roof of the same material.

The vertical walls near the roof are eight windows, covered with gauze. Thus air can enter freely, but flies, which are in and on the filter, are prevented from getting out.

The purification works of the meat factory had necessarily to be different. This manufactory consists of a saltery, a smoking chamber for hams and other meats, a fat-melting house, a sausage boilery, a bone boilery, a gut-sliming house and a slaughtering-house. When there is no slaughtering the waste water, without the cooling water, is very concentrated and fairly constant as to quantity. But when slaughtering, which is not done every day, the quantity of waste water is considerably increased. The design of the purification works was calculated for the slaughter of forty pigs a day. The total quantity of waste water to be purified was accordingly estimated at 50 m^3.

When this quantity is not reached, as is the case when no pigs or a smaller number only are killed, the waste water is automatically mixed with the cooling water, so that the quantity of the water to be purified remains constant. This dilution is always desirable to reduce the very high percentage of salt, which the concentrated water of the meat factory contains.

The cooling water not used for the dilution runs away without any further treatment.

The purification works erected here are constructed so that the waste water first runs through a fat-catcher. The difficulty of properly separating the fat has been solved by means of a cistern, the bottom of which has a peculiar form, so arranged that the water must flow downwards; then the sludge is deposited and the fat rises.

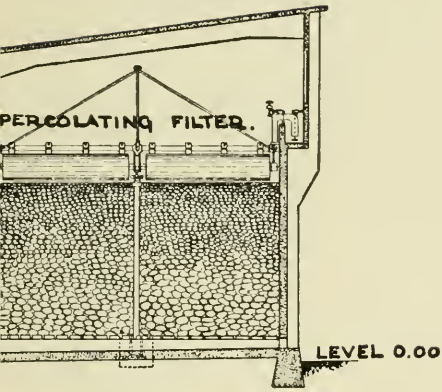
By opening the sludge valve daily, the deposited thick sludge (about two bucketsful) is let off daily and conveyed on the sludge area.

The waste water is pumped from the fat pit into a reservoir, having a capacity of 30 m^3, which rests on pillars of concrete. The space beneath it is arranged as a working-place for the machinist. Sludge, which may still be deposited, is let off by sludge valves to a drained sludge area, 8 m^2, whence it runs together with the sludge from the fat-catcher.

The water flowing from the drains is treated again, together with the effluent from the fat-catcher.

From the reservoir the water runs on to a septic tank, of the same dimensions and the same construction as that of the dairy.

Then the water reaches the percolating filter, which here has a surface of 61 m^2 (15·9 m, by 3·85 m.) and a height of 2 m.



. 6.—Vertical Section on E. F

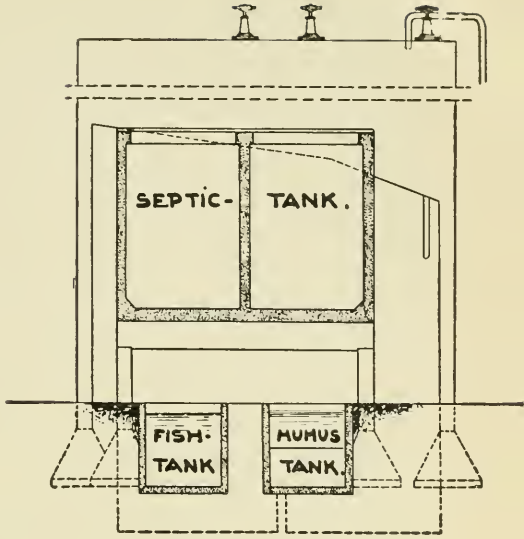


Fig. 7.—Vertical Section on G. H.

The distribution of the water here is quite different. A sprinkler travels continually back and forth. This ingenious contrivance is moved to and fro automatically by a kind of water wheel, which turns the wheels and, at the same time, spreads the water over the surface of the filter. When the sprinkler comes to the end of the filter, it knocks against buffers. This moves a trigger and the sprinkler returns automatically.

This contrivance is used in England in many sewage works ; it works excellently and requires no attendance.

In contrast with the dairy percolating filter, cinders from the refuse destructor at Rotterdam were used for the percolating filter of the meat factory. The lava, delivered to the spot, costs not less than fl. 10.— per m^3 ; this expense forms a considerable part of the whole cost. Therefore it was thought of importance to look for a cheaper material, such as cinders from Rotterdam, which cost fl. 1.50 per m^3 delivered to the spot.

That part below the height of 1.40 m. in the filter of the meat factory was partly filled with destructor slag. A difference of effect has been observed between the two kinds of material ; but it does not seem sufficiently important to suggest the idea that lava slag should always be used.

This filter also is entirely roofed over. On the one side the vertical walls are supplied with glazed windows, on the south-western side with openings covered with fine gauze. There are also two chimneys on the roof covered with copper gauze.

The water from the percolating filter is conveyed to a humus tank with a superficial area of 2 m^2, where the humus is washed out and settles.

Another characteristic feature of this installation consists in the fact that the above-named workplace of the machinist is lighted by the gas (methane), which is produced in the septic tank by the fermentation.

Producing such a fermentation of power gas in waste water with a view to turning it to profit economically, is perfectly new in the literature of waste water. Researches on this point were made a long time ago by Mr. Kessener, and are now being continued on a larger scale by my assistants. A vast field of activity is still open in this matter.

In connection with this, it is important to report that some time ago the Strawboard and Paper Manufactory, formerly W. A. Scholten, at Sappemeer, have, with the gas from their septic tanks, proceeded to work a gas motor and to convert the working energy into electric power.

The water now runs as a clear brook, where plants and fish thrive, whereas before the purification works were erected, the ditch into which the slaughter-house and the dairy discharged their refuse infected the surrounding country.

Both plants have been built very compactly. Their successful working must, in a high degree, be attributed to the fact that they were built with much supervision and care. If purification works such as these are wanted to work well, most careful attention must be paid to seemingly very unimportant points. Indeed Mr. Kessener would have these biological purification works serve as models for others, and convinced as he was of the great importance that their efficient working would have on the introduction of the principle into this country, he has not neglected to give their construction his full attention.

The capital cost of the purification works of the meat factory amounted to fl. 6.200 ; that of the dairy to comparatively much more, viz. fl. 7.000. This difference is the more striking if one bears in mind the above-mentioned quantities to be purified daily. Moreover, it must not be forgotten that the filter of the first mentioned plant has partly been built of the cheap cinders of the refuse destructor. But far the greater part of the difference of costs must be attributed to the different procedures adopted by the two factory boards. The meat factory had the whole work done by one contractor only, the dairy employed several. The working expenses are exceedingly low for both plants.

They both require a small steam pump for the pumping up of the water, and a man to supervise the works from time to time. The little distributor on the filter of the meat factory has to be cleaned once a week. In both works this double task is done by the machinist without any further assistance.

The addition of lime to the waste water at the dairy requires care, for it is important for the working of the purification that enough lime is used to neutralise the mixture ; for if it remains acid, the biological action of the tank is greatly hindered. This can easily be done by the test with litmus paper. Simple as this may appear, the person trusted

CHEMICAL ANALYSES OF TWO WATERS.

Parts per 100.000.

	Dairy.				Slaughtering-house.			Mixed effluents into the ditch.
	Influent septic-tank.	Effluent septic-tank.	Effluent percolating filter when treating		Effl. septic-tank.	Effl. septic-tank.	Effl. per-colating filter.	
			13 m³/day	24 m³/day				
Total Nitrogen unfiltered	18.3	18.0	—	—	49.1	47.9	—	—
,, ,, filtered	14.0	13.5	2.45	3.9	45.9	40.9	8.5	2.9
,, ,, in suspension	4.3	4.5	—	—	3.2	7.0	—	—
Free and saline ammonia	5.25	9.4	1.1	2.4	35.3	36.3	2.85	1.0
Albuminoid ammonia	2.4	2.2	0.38	0.9	9.1	6.65	0.6	0.1
Nitrites (N_2O_3)	0	0	0.2	0.5	0	0	1.8	0.3
Nitrates (N_2O_5)	0	0	4.05	1.25	0	0	9.6	2.8
Permanganate figure 3 minutes' test before (7 days incubation at 30° C.)	23.2	19.2	0.7	3.8	35.3	23.7	6.2	1.0
Permanganate figure 3 minutes' test after (7 days incubation at 30° C.)	—	—	1.5	6.9	—	—	3.4	0.7
Permanganate figure 4 hours' test ..	72.0	42.4	3.8	8.5	98.2	44.4	9.4	2.8
,, ,, in alkaline solution	133.4	71.7	10.6	19.5	182.4	118.5	21.6	7.9
,, ,, in acid solution ..	247.4	112.1	11.9	23.1	—	—	—	—
Solids .. (in the unfiltered water)	414.0	265.0	—	—	960.0	881.0	—	—
Loss on ignition (in the unfiltered water)	210.0	95.0	—	—	180.0	139.0	—	—
Ash.. .. (in the unfiltered water)	204.0	170.0	—	—	780.0	742.0	—	—
Solids .. (in the filtered water)	361.5	248.5	171.2	186.5	902.0	862.0	773.0	173.5
Loss on ignition (in the filtered water)	185.0	89.0	18.7	30.0	168.0	126.0	42.0	18.5
Ash.. .. (in the filtered water)	176.5	159.5	152.5	156.5	734.0	736.0	731.0	5.0
Suspended matter: total	52.5	16.5	—	—	58.0	19.0	—	—
Suspended matter: organic	25.0	6.0	—	—	12.0	13.0	—	—
Suspended matter: inorganic.. ..	27.5	10.5	—	—	46.0	6.0	—	—
Chlorine	57.1	56.5	56.5	56.5	Average 367 p/100.000			—

with it must devote to it the necessary attention, which, however, may be confined to an hour's work daily. The addition of lime is also done by the machinist. The only actual expense necessitated by the purification is the purchase of lime. 10 kg. at the price of fl. 0.085 must be reckoned as the maximum quantity per day.

As has been mentioned above, the two factories have a far greater amount of waste water running through the purification works than that for which they were originally constructed. The dairy lets off at least 24 m^3 daily. One day the quantity was even 38 m^3. But in this case the waste water had been mixed with a considerable quantity of rain-water. Steps have now been taken to prevent any such addition in future. Yet, as a rule, twice the quantity originally intended is conveyed through the filter. As may be gathered from the table on p. 241, the purification can be called perfect, yet so much overwork must, in the long run, bring the good effect of the whole installation into danger.

If the water in the septic tank runs at too high a rate, it works imperfectly. Moreover, the filter has then not only to purify the double amount of water, but besides it will have to digest too much suspended matter, which leads easily to choking.

A similar remark applies to the meat factory. Sometimes sixty pigs were slaughtered in one day. But as a day of slaughter on so large a scale will generally be followed by one when no more than the average slaughtering is done, this overwork makes itself less felt here. The factory is now being considerably enlarged.

The annexed table gives the results of the chemical analyses of the water of the two plants. The large amount of nitrous and nitric salts and the low permanganate figures show that in spite of overwork the purification is more than sufficient.

When put to the incubation test sulphuretted hydrogen was never produced in a sample of the purified water. In Holland these biological purification works are nowadays the first perfect installations of that kind with results satisfactory in every respect.

Attention may also be called to the fact that the commission which by ministerial decision of June 22nd, 1908, was appointed with a view to start researches for the most efficient and least expensive method for purification of the waste water of strawboard and potato flour factories, recommended an analogous method for the solution of the question submitted to them.

The researches of this commission lasted four years, during which time Mr. Kessener was entrusted with the direction of their very far-reaching experiments.

Two years ago a percolating filter was established at the Strawboard and Paper Manufactory of W. A. Scholten at Sappemeer (whose director was one of the members of the commission), for the purpose of purifying a part of the waste water. This example, it is hoped, will be followed as quickly as possible on a very large scale.

SEWAGE TREATMENT IN SCANDINAVIA AND FINLAND.

By Geo. Peel Harvey,

Sanitary Engineer, Copenhagen.

The history of sewage treatment in Scandinavia dates from the commencement of the present century. No works worthy of the name had been carried out previously, and only an occasional very primitive settling tank existed. I have only met with one instance of a tank carried out earlier, that could with advantage be made use of when designing new works.

The capital cities, Copenhagen, Stockholm, Christiania and Helsingfors, being all seaports, discharged at that time their sewage into the sea without treatment, with the exception of Copenhagen, where it passed through coarse screens, before being pumped into the sound.

Other large seaports, such as Trondhjem, Bergen, Gothenburg, Malmö and Aarhus disposed of their sewage on similar lines.

In 1901 the English Septic Tank Company extended its activities to Scandinavia, and the writer came over as engineer to the enterprise; at that time the septic method of treatment was naturally that universally adopted—at the commencement in connection with contact beds—but these were rapidly superseded by trickling filters, due to the latter's greater elasticity and suitability for Scandinavian conditions. Some half-dozen contact-bed plants were, however, installed, and several of these are still in satisfactory service. Among them may be mentioned the works put down in 1902 for the Danish Royal Residence at Fredensborg. This septic tank was first cleaned out in 1914 and the filtering material screened, and in October, 1916, the filtering material was washed, otherwise the plant has only had the ordinary attention of the caretaker and occasional repairs to the original automatic alternating gear, which is still working satisfactorily. Such a record can, of course, only be obtained by the diligent attention of the caretaker, and is a testimonial to the conscientious performance of his duties.

During the ensuing twenty-three years considerable development has naturally taken place and other methods of tank treatment have

come into favour ; installations having been carried out with settling tanks, modified Imhoff tanks, chemical treatment and on the activated sludge principle ; but where the conditions are found favourable the much maligned septic tank is still being used. At the risk of laying myself open to criticism I must say that, in my experience, a well-designed septic tank is the most "fool-proof" of all, and I am not convinced that it is not in quite a number of instances, the cheapest in working costs. I hold no brief for it, making quite as frequent use of other types, where local conditions call for such, but what other type will go on giving tolerable service year after year, when receiving so little attention, as is often the case with small and medium sized installations ?—at any rate, in the countries of my activities—and doubtless many of you can corroborate from experience of works being neglected in the same way.

About twenty years ago, before the trickling filter method was thoroughly tried out, filter plants were built in Norway and Denmark which were a combination of the trickling and contact methods ; a contact period being arranged for in the bottom of the filters, because one was not at that period convinced that the rapid passage of the liquid through the trickling filter would secure sufficient oxidation of the impurities. These, however, probably because they were neither "fish nor fowl," only proved a moderate success, and since then all filter plants of consequence have been of the trickling type.

Almost all methods of distributing the tank effluent over the filters have been tried. Rotary and fixed sprinklers with intermittent dosing under varying head, electrically driven travelling distributors, feed channels and perforated trays with dosing gear, "Stoddart" distributors, and the so-called "Hamburg deckschichtverfahren" better known as "Dunbar's system."

The writer's experience of the latter method is that a comparatively large proportion of the effective area of the filter bed is lost by its division into bays—a serious item when filtering material may cost 15s. per cubic metre—and that distribution is uneven while the fine distributing layer at the surface is "ripening" ; moreover, very soon after the surface distributing "film," if it may be so called, is complete over the whole area of the filter, the material clogs, and the filter has to be put out of action for attention. Both this method and rotary sprinklers, owing to their exposed construction, are seriously affected by the severe cold experienced in Scandinavia and Finland ; protracted periods of frost with the thermometer at −25 deg. Centigrade (10 deg. below zero Fahrenheit) are not unusual and even −35 deg. to −40 deg. C. are occasionally experienced. Under these severe climatic conditions it is frequently necessary to roof in the filters, and it will be readily understood that—with rotary distributors, where it is not easy to obtain central support for the roof (which may be of considerable span and subject to heavy loads of snow)—the roofing in of such a filter may easily add heavily to the initial cost.

Distribution with perforated trays on small filters has also proved unreliable owing to the rapid clogging of the perforations entailing more attention than such plants ever receive.

Generally speaking, it may be said that fixed sprinklers with intermittent dosing under varying head has proved the most efficient method of distribution under these conditions, and is that almost universally adopted in spite of the apparent drawback of the large number of spray jets on large filter units. Experience has shown that this drawback is more imaginary than real.

At the largest filter plant in Denmark, for instance, there are over 20,000 spray jets, but the attention required to keep them in workable condition is by no means appalling, in spite of the fact that owing to the very large increase in the flow, since the original open septic tanks were carried out, these have now only a capacity of three to three-and-a-half hours average flow during the day time, which results in large accumulations of sludge in them and undue quantities of suspended matter being carried on to the filters in the tank effluent. A scheme for the conversion of some of these tanks to activated sludge units for the partial treatment of the sewage before passing it on to the filters is now under consideration.

Reverting to the method of distribution by fixed sprinklers, another important point in their favour is that the sprinkler pipes are almost buried in the filtering material, only the tops of the pipes being exposed, and this has proved a very efficient protection against severe frost, so that many plants of this type have been carried out in Denmark and the southern part of Sweden without roofing the filters in, with a saving of considerable sums of money. Some of these works have operated now from sixteen to eighteen years without any breakage of sprinkler pipes by freezing or serious interruption in the distribution of the tank effluent; therefore the saving in expense may be said to be justified.

Very soon after the introduction of the septic tank system in Scandinavia the so-called "Hustank" (literally "house tank") unfortunately made its appearance. This consisted simply of a small tank—generally of very rudimentary construction and designated "septic tank" built by each house owner, through which the w.c. discharge only was passed, the other domestic sewage being generally led direct to the town sewer without treatment. The sewers in the great majority of both the larger and smaller towns were at that time in a very doubtful condition, and most of the towns were entirely without any sewage purification works. These "house tanks" withheld solids and paper which it was feared would choke the sewers that were in a bad state, and, moreover, the removal of the unsightly elements from the sewage permitted in many cases its continued discharge at the outfall without visible nuisance. Their adoption became, therefore, very general throughout the whole of Scandinavia, thereby permitting acquiescence to the increasing demand for the installation of water closets, and the postponement for

the community of considerable expenditure for new sewers and outfall works. This has proved an expensive postponement for many towns. Had they put their sewers and outfall works in order at that time, it would have been done at pre-war costs. Not only this, but municipal authorities are slowly waking up to the fact that in each house owner who installs a tank, they possibly lose an influential supporter for the final solution of their sewerage problem—which must be solved sooner or later—because the house owner, having at his own expense put his house in order, not unnaturally becomes a less enthusiastic supporter of a complete scheme incurring an increase in the rates.

A few sanitarians have protested against the "Hustank" from the first, and their efforts are finally receiving recognition. In some towns where these tanks were previously prescribed they are now prohibited, and Sweden, which is the most progressive in this respect, has passed a statute forbidding their use, so that in that country they can only be built by obtaining a dispensation.

In a few towns the sanitary authorities were not satisfied with the house tank alone, and prescribed that the discharge from water closets be treated by a complete tank and filter installation of suitable size, before being discharged to the town sewer.

In one large town in Finland, Åbo, there exist to-day probably over one hundred such installations. The houses, which generally consist of flats and are two or more stories high, are grouped round the building site with a yard in the middle, and the size of the plants varies from twenty to 300 people.

It will be readily realised that the designing of such a plant at that time (1905) presented a problem of considerable interest and difficulty, to which was further attached no slight responsibility, since the town authorities made the satisfactory working of the purification plant a condition for their sanctioning the installing of the water closets. In case of failure to obtain satisfactory purification, or if a nuisance was caused, the installation had to be removed. The climatic conditions were severe ; the tank and filter had to be built underground in a yard surrounded by habitations, and provision made for the access of fresh air to maintain aerobic conditions for the filter, and proper ventilation provided for ; finally there was a concentrated sewage to be dealt with, and any smell would be fatal.

Control samples of the filtrate were taken by the sanitary authorities every month. The following table gives the average figures of the twelve monthly control samples taken of the filtrate from eight of these plants during the year 1910. The table also gives the corresponding figures for the water in the "Aura" river, into which the sewage is discharged.

Installation.	Milligrams per litre = parts per million.			
	Total solids.	Inorganic.	Organic.	Oxygen consumed.
The Archbishop's Residence ..	120	80	40	6.02
Slottsgatan No. 3 B	69	50	19	5.44
Kaskisgränd	100	69	31	6.50
Hotel Hamburger Börs ..	48	30	18	5.46
Vesterlånggatan No. 18 ..	83	53	30	8.68
Aktiebolaget John Barker ..	150	117	33	7.27
Aktiebolaget Verdandi ..	57	31	26	6.47
Aktiebolaget Prima	131	73	58	13.80
The " Aura " River Water ..	401	378	23	1.12

The last installation of the list is the first one carried out in 1905, and represents thus the results after five years working. The average oxygen consumed figure for this plant for the preceding year was 13.46 p.p.m. If we accept an oxygen consumed figure of 1 grain per gallon (equals 14 p.p.m.) as a reasonable standard of purity for filtrate from plants working under these conditions, it will be seen that all the results satisfy this standard. In fact, it will be admitted that the results are surprisingly good and show that even under such adverse conditions such plants can, if properly designed and looked after, effect a very considerable degree of purification.

At Helsingfors, the capital of Finland, the outfall conditions are difficult and complicated. A part of the sewage is discharged into the sea around the coast without any nuisance, but the sewage from other districts of the town discharges into harbour basins in some of the busiest parts, and yet other districts are drained respectively to a small stream and to a comparatively small body of water, with very little circulation, lying almost entirely surrounded by the town. At the first of these two outfalls septic tanks and covered trickling filters with fixed sprinklers, followed by humus tanks, were carried out in 1910, and at the latter in 1914 septic tanks with filters provided with Ham Baker motor-driven distributors, followed by humus tanks. The extension of the first of these works is under consideration at the present time.

Plants have been installed for breweries, leather, paper and bone and meatmeal factories, gut-cleaners and about a dozen slaughter-houses. In these latter various types of construction have been tried out, comprising fat interceptors and screening tanks, septic tanks, modified Imhoff tanks, and separator settling tanks, both with and without contact or trickling filters. The three principal difficulties in dealing with this class of trade waste arise from the so-to-speak " undigested " state of the organic impurities, the large amount of grease it contains, and its smell.

Judging by results in Scandinavia there is not clear evidence to justify giving a distinct preference to any one of the above-named methods of preliminary treatment. It is under any circumstances a difficult waste to treat satisfactorily, and one approaches it with considerable respect after a few years' experience.

A couple of years ago my firm designed a plant to deal with the waste of a large yeast factory at Rotebro in Sweden, for the Swedish Yeast Factory Company. The principal sources of impurity in this waste are the steep-water, and the so-called "brännvatten," the residue after distilling the alcohol from the yeast liquor. This residue is strongly acid, evil smelling and extremely concentrated.

An examination of the condition of the lake, which received the untreated waste from the factory, was made by Professor K. Sondén, of Stockholm, in July, 1922. His report showed the lake water to be severely polluted, particularly in the neighbourhood of the factory's outfall, but also in other deep places large deposits of putrefactive organic matter were located. The lake is usually completely frozen over from November to April, so that no surface oxidation of the water can take place during about four months of the year, and during this period the robbing of the water of its oxygen contents by the factory liquor is further aggravated by the deposits of putrefying matter on the bottom, so that when the ice breaks up an abominable nuisance from smell is created. Professor Sondén estimated that the factory turned about 2,200 kilogrammes of organic matter into the lake daily, equivalent to the sewage from about 50,000 people. The standard of purity he sets up for the lake water is as follows: that it shall under no circumstances be evil smelling, that it shall be usable for laundry purposes and as drinking water for cattle, and that fish can live in it. It fulfilled none of these conditions on the occasion of his examination. The dredging up of the worst sludge deposits, which he recommended, was not carried out.

Analyses which Professor Sondén had made earlier of the "brännvatten" from another of the yeast companies' factories at Nässjö, showed this to contain approximately 10,000 to 11,000 parts per million dry solids, of which about nine-tenths were organic matter, while it had an oxygen consumed figure of between 4,000 and 5,000 p.p.m. He showed it to be about twenty-five times as strong as Stockholm City sewage with an oxygen consumed figure of 180 p.p.m.

Early in 1920 my partner, Captain Jarvis, had carried out experiments with the Nässjö factory waste, with which we were then in touch. The liquid was coagulated with lime and filtered through an experimental filter 2 m. deep of clinker from a filter that had been treating sewage for twelve years. Samples of the filtrate, taken at the close of these experiments, kept six to ten days at room temperature, without smell.

In October, 1921, these experiments were repeated with a sample of the Rotebro factory's liquid, and in December the factory sent us another very large sample. The test with this lasted until the begin-

ning of March, with results similar to those of the previous experiments. During January and February very severe cold was experienced, and the experimental filter developed grey growth and had to be reconstructed. On the basis of these results the Rotebro installation was built, at a cost of about £5,000, and put into action on October 1st, 1922, two years being allowed in which to obtain the anticipated results.

The discharge varies greatly throughout the day, both in quantity and quality. Two equalising tanks were constructed in order to obtain a liquor of as even nature as possible for the lime dosing. The lime for neutralisation and coagulation is added by automatic apparatus of simple construction, and at the same time a dose of bleach solution for deodorising, by another intermittent automatic contrivance.

The liquor is then pumped over measuring weirs, with flow indicators, to the neutralising chamber and passes to two settling tanks from which it is taken off at the surface by collecting channels, while the sludge can be drawn off daily from pockets at the bottom by hydrostatic head to a sludge concentrating and digesting chamber with floating arm and draw-off valves. After passing the two secondary settling tanks the effluent is dosed by automatic intermitting gear and varying head fixed sprinklers on to two trickling filters, which are 2 m. deep.

As the effluent is quite warm, it was decided not to roof over the filters although very low temperatures prevail. The filters have worked through two winters without trouble. The filter sides become a sheet of ice, but even distribution on the surface can be maintained.

The filtrate passes finally through two humus tanks, from which the humus can be pumped back to the sludge digestion chamber. From this chamber concentrated sludge can be tapped direct to carts by hydrostatic head, or run off into two underdrained sludge bays for drying before removal.

The factory had estimated the flow to be treated at 500 m^3 per day, and provision was made for a 20 per cent. dilution of the liquor with lake-water pumped up for this purpose. On starting up gaugings showed the flow to be from 750 to 1,000 m^3 d., or nearly double the estimated flow, of *the same strength liquor* as the samples sent us for our experiments, because these were average representative samples.

Already by the end of October a grey slimy growth and a white mould appeared on the filter surface, causing ponding. A microscopical examination showed these growths to be of gelatinous nature and containing lactic and acetic acid bacteria, yeast bacteria and another comma-like bacterium. The filters were dosed temporarily with weak lime solution, and it could be seen under the microscope that this had a dissolving effect on the gelatinous matter. On November 3rd the surface of the filters was sprinkled with a watering can with a 20 per cent. caustic soda solution, 1.5 litres per square metre ; by 4 p.m. the next day ponding had practically disappeared. On November 6th the ordinary grey filter fly (*Psycodidea*) made its appearance, and it was noticed that its larvæ were most numerous where there was a slight tendency to ponding.

Only about 40 m^3 per day of tank liquor was allowed to go on to the filters at first, and this was gradually increased up to 180 m^3 d. during the succeeding two months, and still later to 240 m^3 per day.

Some smell was experienced around the works, but this was greatly reduced by the deodorising bleach solution, 20 p.p.m. free chlorine being added.

The sludge in the settling tanks evinced a proclivity to "boil up," due no doubt to the rapid formation of gases, which again was accelerated by the liquor's high temperature. This high temperature was maintained throughout the plant even in February with the thermometer at 10 deg. below zero Fahrenheit.

When the ice on the lake broke up in April, 1923, the usual aerial nuisance and greenish yellow colour of the water of previous years were absent. The water had only a "seaweed" odour, and many small fish were seen, which was something quite new.

In May, 1923, filter No. 1 again showed signs of ponding and sub-surface growths. The top layer of clinker, which had been poorly graded from the first, was washed and regraded. As there was still some tendency to pond on filter No. 2, it was decided to inoculate the filters with *achorutes viaticus*, and a letter to Mr. Herbert D. Bell, at Barnsley, met with a ready response and detailed instructions for the inoculation. He very kindly despatched at short notice one box of medium with adult insects and two boxes containing large numbers of eggs, and the filters were inoculated during the first week in July. On September 5th the writer examined the insect life on the filters and found innumerable colonies and eggs of the *achorutes viaticus*, not at the points of inoculation, but principally at the sides about ten yards away and in the pigeon-holing of the filter walls. Further inspection disclosed the presence both of white and red *acarinæ*, and of large numbers of the *Podura aquatica*, a contemporary of the *achorutes viaticus* and resembling the latter superficially, but not so active and numerous, Mr. Bell tells us. There were also numerous minute white worms and, of course, the grey fly (*Psycodidea*), which is expected to disappear through the *achorutes viaticus* feeding on its larvæ, and also slim, fierce-looking beetles about 10 mm. long, the shape of an ant, which were very active.

As the *achorutes* were spread around the sides of the filters and did not seem to be getting on with their work, like Mr. Easdale reports them to have done at the installation which came under his observation, but rather "walking round it," so to speak, it was decided to collect them from the pigeon-holing and attempt seeding systematically along the sides of the sprinkler pipes, because the amount of effluent distributed close to these between the jets is slightly less than elsewhere.

About this period Captain Jarvis made some experiments, using sulphate of alumina and sulphate of iron as coagulants. The latter gave inferior results, the former better coagulation than the lime, but as no

definite improvement could be detected in the tank effluent, the lime treatment was adhered to.

During August the flow to the filters was increased to 540 m^3 per eighteen hours working day, and at the beginning of September to 600 m^3. Samples of the filtrate at this period were opalescent, with only an earthy smell, and it had a generally good appearance, while the condition of the lake-water around the outfall was satisfactory.

At the beginning of February, 1924, a new kind of growth (? *Dermatium pullulans*) made its appearance on the filters. It was bright red in colour and of a tenacious gelatinous nature, and developed along each side of where the jets of water from the sprinklers fell on to the material. As it was not very widespread, and we did not want to risk harming the *achorutes viaticus*, it was decided to await further developments, but in the beginning of April it was considered advisable to take action, and the growth was " painted " with a 20 per cent. solution of caustic soda, care being taken not to spill the soda elsewhere on the filters. This retarded but did not exterminate the growth.

This year the ice did not break up until the first week in May, after the lake had been frozen over upwards of five months, one of the longest periods on record. This was a very severe test, but there were no dead fish, no smells, no greeny-yellow discolouration of the water, and all were agreed as to the improvement effected. Early in February Professor Sondén had had samples taken, and these showed much better conditions than of old.

The number of *achorutes* visible is not so great as we could wish. Probably the unprecedentedly long and severe winter, before they were acclimatised, seriously inhibited their growth, or they may have sought a warmer habitat in the interior of the filter.

I have dwelt perhaps with undue length on this plant, but it is unique in Scandinavia, no attempts at biological purification of yeast factory liquor having previously been made. The difficulties that cropped up —some unexpected, some foreseen—have presented problems of particular interest, and my hope is that they may be of interest in other countries.

At the yeast factory and spirit distillery at Rajamäki, belonging to the Finnish Government, similar trouble has been experienced in disposing of the waste liquor. The local conditions were such that we recommended the activated sludge method there. The conversion of a large existing tank on the compressed air process is in progress. It is hoped that this tank, when converted, will prove capable of treating about one-fourth of the present total flow of 700 m^3 per day. When this paper was suggested, it was anticipated that the first results from the new plant would be available, but unfortunately this will not be so.

At present only two activated sludge plants have been built in Scandinavia, both being in Denmark. The first treats exclusively the water closet sewage from Messrs. Burmeister & Wain's shipbuilding yard at Copenhagen. It is designed to treat the flow from 1,500

employees and is carried out in armoured concrete entirely underground; in fact, it lies under the dockyard quay. This plant was started up in August, 1920.

The other plant is for the Urban District of Holte, about ten miles from Copenhagen. This is for a population of 5,000 and was commenced about the same time as the foregoing, but owing to repeated delays was first put into action in April, 1923. The purification obtained s excellent, but as you have possibly had a surfeit of activated sludge in the ten papers already presented, the writer will not indulge in details.

The foregoing by no means professes to present a complete record of sewage treatment in Scandinavia, but rather touches only on certain conditions and features that may prove of interest.

Professor Alf. Lutken, Director of Technical Education, Copenhagen, has recently written a treatise on the River Conservancy Boards of Denmark, which was presented before the League of Nations Medical Officers of Health Congress held at Copenhagen this June. I would refer those interested in this side of the subject to this treatise, which has been translated into English.

DISCUSSION.

Mr. HARRISON P. EDDY asked, referring to Mr. Kessener's paper, whether any preliminary treatment was given to the strawboard waste before this was treated by the activated sludge process.

Dr. MERCER (New Zealand) said that he would like, as a medical officer, to thank the gentlemen who had read these papers on the treatment of trade wastes. This was a subject which deeply concerned the medical officer as well as the sanitary engineer. Mr. Eddy had given the keynote in the broad outlook which he had taken for the treatment of trade wastes, and also in asking that a reasonable standard of purification should be required. There was only one trade waste with which he (Dr. Mercer) was immediately concerned. In New Zealand now, as in the Old Country, and in the Free State of Ireland, there was a problem of dealing with the trade wastes from factories where butter and cheese were prepared. The effluent from a domestic septic tank which had ceased to function would smell "some," but the trade effluent from a cheese factory where it was put on to the land, could, in that respect, beat the septic tank hollow. This problem had to be dealt with in New Zealand, and he wanted to thank Mr. Kessener because he was the first man to put forward some detailed mechanical scheme to deal with the trade wastes of milk factories. But he wanted to ask Mr. Kessener, Would that scheme efficiently treat whey from a cheese factory? And he would also like to ask, What was the cost? Could he give a rough estimate of cost for a factory turning out, say fifty tons of butter or cheese per week?

Mr. NANDY HOSKINS said: Few trade wastes have presented greater difficulties than milk waste or the waste from cheese factories. The putrefactive nature of milk is well known and when we say that the waste from cheese factories is ten times the strength of town sewage the statement does not convey any useful comparison—the polluting content is of an entirely different character to that contained in domestic sewage. Dairy waste when fresh, or even a few days old, has no objectionable odour and it is not until the buteric bacteria have developed in sufficient numbers that it is really offensive.

Both in this country and on the continent I have invariably found that when this waste has been turned on to the land or into streams of even moderate volume nuisance has arisen, due to the growth of *oospore lactis*. These remarks apply also to the treatment of milk waste on artificial filters, without first special preliminary treatment. I have seen filters entirely clogged with this gelatinous fungus. Such filters are happy pleasure grounds for *achorutes viaticus*.

The difficulty in dealing with dairy waste is due to the rapid development of the lactic acid bacteria; as they increase, so does the acidity of the liquid, and from my experience it is not possible to purify the liquid while it has an acid reaction.

It can be rendered neutral or alkaline by the addition of lime, but this is only temporary—the bacteria rapidly develop and the liquid is again acid. The quantity of lime added is also important having regard to subsequent treatment and depends entirely on the acidity of the liquid being treated. The best results regarding the deposition of solids are obtained when the liquid is neutral; within a few hours, however, the reaction is again acid and a quantity of colloidal matter develops.

After experimenting with some thousands of gallons of this waste over a period of several months I came to the conclusion that it could not be treated successfully by aeration or filtration unless the growth of the acid forming bacteria could be stopped, or at least checked for a sufficient length of time to deal with it. Many chemical agents were tried and also ozonizing out without success.

I did find, however, that it was possible to upset the developing energy of the bacteria by treating the waste electrically.

Having accomplished this, there was no difficulty with the aeration plant at my disposal and subsequent filtration to turn out an effluent (depending on the amount of treatment) of any degree of purity.

Dr. ARDERN said he would like to express his appreciation to Mr. Eddy for a very concise and informative paper on the question of trade effluent disposal. He thought Mr. Eddy very rightly stressed the extraordinary effect which the addition of certain trade wastes had on the character of the sewage of certain specific localities. He had been very much interested to see the basis on which Mr. Eddy calculated this effect, because it was not easy to put into simple language the effect of any individual trade waste on any particular sewage. The tests used in

analysing were purely empirical, and did not distinguish between varying types of organic matter. You might have two trade matters with a similar oxygen absorption, but so far as purification was concerned they might be entirely different ; for one might be easily purified by the commonly adopted methods of purification while the other might represent retrograde matter and give great difficulty. At the moment we could only summarise the effect of trade wastes from the tests we employed and these might to some extent be somewhat elusive. Sulphate of ammonia effluent was highly oxidizable, but unless the amount was excessive it would not necessarily interfere with sewage purification as practised by plants in this country. On the other hand, you might get effluents with very much less oxidizable matter as effluents from the manufacture of dye stuffs which would create very much more difficulty at the purification plant. He would like to ask Mr. Eddy if he had had any experience of the separate treatment of waste liquor from sulphate of ammonia plants, or conversely of the effect of the presence of sulphate of ammonia effluent in industrial sewage—the effect on its treatment —and, secondly, whether there were any large or small industrial cities in the United States where the sewage contained a relatively high proportion of waste resulting from the manufacture of dye stuffs. There was a rather curious effect in Manchester, where they had probably a greater proportion of actual chemical trade wastes in their sewage than was contained in almost any other sewage in this country, and as a matter of actual fact he had come to the conclusion that the residuals from the manufacture of dye stuffs probably interfered more with the bacterial oxidation of sewage matter than almost any other of our trade wastes. You could get practically colourless sewage coming into the plant with a very strong colour produced in the final element, and the only conclusion he could arrive at was that there was a process somewhat akin to the manufacture of dye stuffs taking place in the aeration plant. He had been very much interested in the regulations formulated by a committee of the Sanitary Section of the American Public Health Association, particularly in this respect, that he wondered what criterion they had for determining whether or not a water was suitable for consumption by cattle. That was a point that had arisen many times in his experience. He would not express an opinion upon it, but he had heard a Medical Officer of Health state that cattle could drink septic sewage without any detriment whatever and would even prefer it to pure water. He imagined that eventually the problem was more veterinary than chemical or biological, but it was interesting, seeing that it was specifically mentioned that the water should not be injurious to cattle. He wondered what standard they had in America in determining what was injurious ? Another point of very great interest was the idea that treatment should be varied according to the flow in the river and climatic conditions. He thought this very good, and, of course, no one could quarrel with it in theory, but how it would work out in practice he did not know. If it was going to be left to the manufacturer to determine when he should

adopt the complete or partial or entirely discontinue his treatment, it would raise a very difficult question for those concerned with the control of the pollution of rivers. It was only reasonable, but you were placing a great difficulty on those responsible to say that pollution did or did not actually occur. He would like to know why sodium nitrate had been used. He should have thought that manganate of soda would have been as cheap or cheaper for oxidation purposes. He would like to ask one or two questions with regard to Mr. Kessener's paper. With regard to the application of the activated sludge process to the treatment of milk waste, was Mr. Kessener able to say whether a preliminary anaerobic treatment was advantageous? Mr. Poole Wilson, working for the Board of Agriculture in Ireland, had carried out some experiments, and came to the conclusion that it was a decided advantage to have a preliminary anaerobic treatment of the milk waste. He, Dr. Ardern, would also like to ask Mr. Kessener whether he had gone far enough with the experimental results of the activated sludge process as applied to the treatment of those various products that he had dealt with, to say whether such process in addition to being able to yield a satisfactory effluent was practicable from the cost point of view?

Dr. H. T. Calvert (Ministry of Health) said he had listened with very great interest to Mr. Eddy's paper, which was an admirable resumé on the subject of the treatment of trade refuse. He was sure that Mr. Eddy had put everything into as small a nutshell as he possibly could. They had heard that afternoon some criticism of the requirements of the Ministry of Health as regards design and capacity of tanks and filters, and perhaps it was well known that those requirements were based upon the recommendations of the Royal Commission on Sewage Disposal. He would very much like an expression from some of their American colleagues as to the extent to which they in their practice adopted those recommendations.

With regard to Mr. Kessener's paper he appreciated the difficulty under which Mr. Kessener was labouring in attempting to concentrate such a large amount of work within the small time at his disposal, and the same remark applied to the scientific work described by Mr. J. A. Wilson on the previous day. He had read Mr. Kessener's paper with very great interest, and felt that he had done an admirable work in attempting to solve the problems of trade refuse disposal in an agricultural country. The author of the paper struck several notes, more especially the questions of utilisation and dealing in a similar manner with the kinds of refuse which had similar composition. He had particularly noted how the sugar factory refuse was reused and treated in such a way as to get as much sugar as possible out of it before it was discharged, and how the strawboard factory refuse was utilised to yield combustible gas. From 135 tons of straw only 100 tons of strawboard were produced. The rest went away in the waste waters, and Mr. Kessener had attempted to convert some of that enormous percentage into gas. He

(Dr. Calvert) had not only read Mr. Kessener's paper with interest, but it had been his privilege a short time ago to visit some of the works described by Mr. Kessener and he was full of admiration for the large amount of scientific work carried out by Mr. Kessener, and for the excellent manner in which the results of this scientific work had been applied on a large scale.

Mr. George Fuller (New York), replying to the invitation of Dr. Calvert, said it was rather difficult for an American engineer to state very directly and authoritatively the extent to which the teachings of the Royal Commission on Sewage Disposal were used in America. He would say in the first place that the underlying principles that were developed as the result of those inquiries had been very fully appreciated in America, and that Americans had learned a great deal from them. They had certainly been very much under an obligation for the information developed through that channel; but when it came to practice, the conditions in America were so different from those here that he did not believe there was a very ready comparison to be made. In respect to grit chambers, or as they were called in England, detritus tanks, he would say in the first instance that where sewers were built on a separate system the detritus tank was rarely used in America. When it was used it was under some special condition, as when the tank was located near the inlet of some long syphon which was difficult to clean in the event of any obstruction. In regard to the grit chambers in connection with the flow of sewage on a combined system, there he thought that nearly all of the recent installations had been of the type shown on the screen by Mr. Hatton as the result of his decisions for the plant that he was completing at Milwaukee. This was similar to what Mr. Hurd had shown in respect of the Indianapolis development. The fundamental rule was that velocity was to be brought down to from six to twelve inches a second. Another matter was that grit chambers in America were generally short. There were at least two and usually more than two. Their success depended on the operator and the facilities with which his mechanical appliances allowed the grit to be removed. There were not so many of these individual grit chambers which could be put into service one after another, and they would not serve their purpose unless there was a very good set of arrangements for their being cleaned during the period of storm. After deposit occurred in the chambers, if they were not cleaned out they became no better than the sewers themselves. So far as concerned the ordinary plain sedimentation tanks, these were scarcely ever used in recent installations in America. Almost always the two-storey tank was used, although there had been a number of small installations that he presumed were following the lines substantially of British practice. In America they found that three or four hours was long enough in the detention pit, and then in order to prevent troubles arising it was a question of the number of units to be specified.

Dr. H. Maclean Wilson (West Riding Rivers Board) said that he could not really say much about the papers as he had not had time to study them, but one point he would like to mention in connection with the treatment of dairy refuse. A good many years ago he had gone into the question very fully, and had found a dairy where cheese was made, where the refuse was very efficiently dealt with by septic tanks very large in comparison with the flow—of several days capacity—and afterwards by repeated percolation filters. The effluent went into what was a stream in winter, but was practically dry in summer except for the dairy discharge. It was beside a public road leading to a railway station, but there was no nuisance. Of two other instances, neither of them large places, one was an experimental farm belonging to a county council in Yorkshire. There the dairy refuse was dealt with, without the whey, by irrigation on grass land, and had been so dealt with for fifteen or twenty years. There was a large area of grass land, and no discharge to a stream. There was no nuisance and no pollution. Another instance was that of a dairy belonging to the Wholesale Co-operative Society which discharged the dairy refuse into small sewage works which otherwise dealt only with the sewage of some fifty houses. These sewage works were too small even for the domestic sewage, so it was no wonder that the result of discharging the milk waste into them was bad, and the smells horrible ; but some six or nine months ago he had persuaded the district council concerned and the dairy people to pipe this effluent of mixed sewage and milk washings on to a piece of land where it was absorbed, and there was no nuisance. There was a little effluent into a stream, but it had been causing no sign of pollution except that from the land on which this was irrigated there was a great discharge of ochre water which no doubt helped to dilute the effluent, and also had the effect of causing a very profuse growth of a fungus kind. He had sent his inspector to get samples of this, but although at the time of his own visit the whole bed of the stream had been covered with this fungus, when the inspector went a fortnight later, after a slight freshet there was none left. He (Dr. Wilson) thought the best results with dairy refuse had been got by prolonged septicisation, and afterwards percolating filters. He had no experience of treatment of dairy refuse by activated sludge, but he thought it could be dealt with in that way.

With regard to what Dr. Ardern said, the question of chemical refuse from gas liquor was a very difficult and striking one. He had cases under his care where the proportion was perhaps ten per cent. or more of chemical refuse in comparison with the flow of sewage with which it was mixed. No doubt such a mixture did very materially interfere with the treatment of the sewage. He knew that in the cases of Rotherham and Sheffield, where they were treating sewage now by activated sludge, they found quite an interference with the treatment, although the proportion of that kind of chemical refuse did not amount to the two per cent. mentioned by the Royal Commission. It was a

great difficulty, and he would like to know if any present had done anything to overcome that difficulty.

Mr. EDDY said that fortunately he had not been confronted with the problem presented by ammonia effluent and the waste from gas works, so that he could not give Dr. Ardern any information upon that point. With respect to the cost of potassium permanganate and sodium nitrate this had been a comparatively small matter. The introduction of the sodium nitrate had been an emergency measure and had lasted but a very few days, under two weeks, on each occasion. Its use might have been a matter of convenience ; they might have had sodium nitrate at hand, and not potassium permanganate. With reference to what had been called the regulations of the American Public Health Association, those were hardly regulations ; they were simply suggestions by a committee as to what might constitute a reasonable basis of dealing with the question of stream pollution, and the discharge of trade waste and sewage. There was no regulation, he thought, not even a suggestion, as to the standard of purity of water for watering cattle. He thought the only reference to that subject was that he had mentioned it as one of the reasons for treating trade waste ; it had been necessary to treat waste so as to protect the water supply to cattle. With reference to the method of computing the effect of trade waste upon sewage he had taken what information he could obtain. He recognised that the suspended solids and the oxygen consumed were by no means all that might be desired, but in some cases the suspended matter was a very good measure. It certainly had to be dealt with in many cases, so that he thought probably that any gauge they might select would include that. They would prefer in many respects to use the bio-chemical oxygen demand instead of the oxygen consumed. He had used the latter because he did not have information as to the former except in one or two cases which originated in his own office. He thought the most important question raised was that by Dr. Ardern with reference to the administration—and by that he meant the governmental administration—of the sanitary laws and regulations on a seasonal basis. He might say in the first place that the practising engineers occupied a rather favourable position, because they were the representatives of the manufacturers rather than of the State authorities. They had been a sort of an intermediate party. Whether that was the reason that the manufacturers had done what they had asked them to do he did not know, but he did know that at the outset the manufacturers had raised strenuous objections to the regulations of the State Department, which, in the case that he had used as an illustration, was the Massachusetts State Board of Health. The matter had even gone to the courts, but had been dropped by both parties some ten years ago. He thought the advisory engineer could perhaps smooth the way both for the administration officials and the manufacturers in some of these problems. A very important consideration was the cost. The illustration that he had given was more

or less dependent upon the fact that certain disposal works had been built before the seasonal variation in treatment had been adopted. An annual expenditure was incurred of between $30,000 and $40,000 for treatment even limited as he had described. Were they required to carry out the same degree of treatment throughout the year the annual expenditure would be several times what it is now, and would be a very serious handicap to the industry. This case was by no means the only one, he could have given others within his own knowledge and experience. A paper mill situated on the same river was treating its wastes according to a similar seasonal regulation, and was spending annually for that treatment some $30,000 or $40,000. Since the higher prices the figure had been nearer the $40,000.

Mr. Kessener said in reply to Mr. Eddy that when strawboard waste was treated with activated sludge, it had a preliminary treatment in a fermentation tank in order to remove the alkalinity and the fibres which would give difficulties.

Dr. Mercer had asked about the cost of biological treatment of whey. It was difficult to give exact figures, as no purification works for whey were built in Holland, where it was not permitted to discharge whey. The farmers must take it back. Whey had a concentration of about 100 times that of sewage, and the cost of treatment could perhaps be calculated from that figure.

With regard to Mr. Hoskins' remarks, they had found in Holland that irrigation on sandy soil gave very satisfactory results. It was only when they had clay or peaty soil that they could not purify milk waste by irrigation but had to treat it by biological means. It should, however, be irrigated in a fresh condition, because when a lactic acid fermentation had set in, it was more difficult to get a well-purified effluent. Moreover, it was then necessary to add a great deal of lime for the neutralisation of the lactic acid, which was continuously formed from the lactose.

Dr. Ardern had asked about the cost of treatment of dairy refuse by the activated sludge process. This is dependent on local circumstances, and the time during which power of the factory is available. If, e.g., milk is received twice per day, so that the steam engine driving the air compressors or paddle wheels is running many hours at a stretch, the cost is lower than if the factory runs only a few hours daily. Large aeration tanks will generally be advantageous.

As to the refuse from potato flour and strawboard works, this could be treated very satisfactorily by the activated sludge process, which in some cases would be more economical in Holland than percolating filters. Filtering material was very expensive, because the cost of transport was very high, but generally the cost of power was low for those factories which made the electricity themselves.

Mr. G. Peel Harvey (Copenhagen), replying to a question that had been asked, said that when he talked of standard strengths of sewage

of course it was only a standard in a very rough way. They used the oxygen consumed figure in Scandinavia because it was very seldom the analysts made their analyses in the form of dissolved oxygen required. They considered themselves very lucky if they got an analysis at all, and when they got it it was in the form of oxygen consumed.

The Conference then adjourned.

ENGLISH AND AMERICAN HOUSE DRAINAGE.

By George C. Whipple.

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In connection with a recent study of plumbing regulation undertaken by two committees, one of the Massachusetts State Department of Public Health and the other of the United States Department of Commerce, the writer took occasion to compare English and American plumbing practice and its legal regulation. Thanks to Mr. Michael Hazeltine, Mr. H. C. H. Shenton, and others, he has had opportunity to examine the Model By-laws of the British Ministry of Health and plumbing plants of housing projects, as well as English text-books, scientific reports and trade catalogues. His personal familiarity with English practice has been casual, and he must therefore ask for indulgence in the event of any inadvertent misstatement of fact. The differences of practice in the two countries are considerable and, considering the common origin of plumbing regulation, are difficult to explain except on the assumption that tradition rather than science has been the dominating force. If this is the case, then, recognising the changes which have occurred in sanitary science since the first regulations were put into effect, it would appear to be time to make a thorough study of the whole subject to ascertain the extent to which theory and practice have drifted apart. Such a study has already been begun in America, and it is with the hope that sanitarians in England will also give attention to the long-neglected subject of house drainage that this paper has been prepared. With the enormous demand for houses and with the cost of plumbing forming a large part of the building cost (in America it is from 10 to 15 per cent.), the present would appear to be a favourable time to conduct such studies in order that speedy advantage may be taken of possible economies.

AMERICAN INVESTIGATIONS.

Before making any comparisons of plumbing practice, it may be of interest to English sanitarians to learn of the studies made by the United States Department of Commerce Committee, the report of which was signed on July 3rd, 1923, and which is now available as a Govern-

ment document. Secretary Hoover appointed this "Sub-Committee on Plumbing of the Building Code Committee" in the autumn of 1921, to study the subject and make such recommendations as might seem advisable after scientific investigation. Through the hearty co-operation of Dr. S. W. Stratton, then head of the United States Bureau of Standards and now President of the Massachusetts Institute of Technology, arrangements were made to have two physicists assigned to the task, ample facilities being placed at the disposal of the committee. An unused elevator shaft gave opportunity for the installation of experimental devices and the reproduction of plumbing systems of one-, two-, and three-storey buildings.

Typical plumbing installations were first tested and then the scientific analysis of the whole subject began. Starting with a study of the rate of discharge from water closets and other fixtures, studies were made of the capacities of soil pipes and vent pipes, the usefulness of different methods of "venting," the effect of a discharge from one fixture upon the discharge from another, the relative value of different fittings, the effects of backwater, rain, frost, and other climatic and structural conditions. The work was actively continued for more than a year, and a vast amount of scientific data was secured. A summary of these physical studies and the conclusions drawn from them are set forth at considerable length in the Committee's report. Although many tests of stacks (i.e., vertical pipes) and traps had been made in recent years in different parts of the country, the conclusions derived from them have varied greatly. The scientific work done at Washington enabled many of these differences to be reconciled, and this is one of the points the writer wishes to make—*the subject of house drainage needs and is worthy of scientific study.* When one considers the vast sums spent for plumbing in England and the United States—millions of dollars every year—even a small percentage of saving, if it can be made without injury to health, will be for the good of all the people. The general conclusion of the Washington committee is that in America such savings are possible.

PLUMBING REGULATION.

Plumbing regulation is of English origin. Without attempting to go into the early history of the subject, it may be said that the rules now in force in Great Britain derive their authority from the Public Health Acts, notably that of 1875. Throughout England and Wales all local authorities have power to enact by-laws dealing with the drainage of new and existing buildings and even to enforce house owners to provide drainage under certain conditions. The Ministry of Health, to which were transferred on July 1st, 1919, the powers and duties of the Local Government Board (dating back to 1872), has issued Model By-Laws in draft form for Urban and Rural Districts, applying to new and existing buildings. These by-laws, having no force in themselves, are promulgated for the guidance of Local Authorities. The situation is different

with respect to by-laws for preventing the waste of water. These depend upon special Acts of Parliament which confer power upon Local Authorities or water companies to make by-laws, subject to approval by the Ministry of Health. It may be noted that the Model By-laws relating to house drainage form a part of the by-laws regulating buildings and streets.

In America, the Federal Government has no police power to enforce plumbing regulation. There is no national health department, and the United States Public Health Service, the nearest approach to such an authority, has not concerned itself with house drainage. The United States Department of Commerce took up the subject in connection with a study of the housing problem ; but the Model Plumbing Code prepared by the Committee can be at most only a guide to States, cities, and other communities. In America, the police power rests with the several States, and, as one might expect, great differences exist in their plumbing laws. For the most part authority to set up and enforce plumbing rules has been delegated by the state legislatures to local authorities, although some state plumbing codes exist. To quote from the committee's report, the situation with respect to plumbing regulation is " chaotic." In most places the plumbing laws have to do with drainage only, control of the distribution of water in buildings not being included. The Plumbing Committee's Model Law, however, contains sections which relate to the water supplies of plumbing fixtures. Plumbing laws are ordinarily separate—coded separately and not as a part of building codes, and their administration is more often in the hands of health departments than of building departments.

Much stress is laid in America on the requirement that plumbing work be done only by " licensed " plumbers, but this provision varies all the way from a mere registration of plumbers to the issue of certificates of competency, on the basis of written and practical examinations. Separate licences are issued to master plumbers and to journeymen. The licence system, coupled with labour union rules, has been the cause of serious complaint. While covering their resentment under numerous jokes about the plumber's habits and proclivities, the American people are chafing under a situation which they find it difficult to correct. England, if I am correctly informed, does not have this rigid licence requirement, although plumbers are often registered. There, specifications commonly provide that the work be done by " registered plumbers or men well known as good workmen," and apparently many good plumbers are not licensed. Neither are drain layers required to be licensed. The recommendations of the United States Department of Commerce Committee are in favour of liberalising the licensing system, without altogether doing away with it. While it must be admitted that the licence system has had the effect of improving the quality of plumbing work done, its legality is questionable.

Turning now to the general design of house drainage systems, American practice is founded on what may be called the single stack (shaft) indoor system, in which a vertical interior " soil stack " receives trapped connections from wash basins, bath-tubs, kitchen sinks, and laundry trays

(troughs), as well as from water closets, and which is continued as a horizontal " house drain " (within the house) and " house sewer " (outside the house) to the street sewer. In other words, there is usually one continuous pipe from the street sewer to the ventilating roof-terminal with many inlet connections in its course. Sometimes, it is true, there is more than one vertical stack in a building, but where this is the case the purpose is to avoid long horizontal branches, or fixture drains, rather than to discriminate between different kinds of wastes. In most sections of the United States the soil stacks are inside the building, but in some of the warmer regions they are placed outside. English practice, on the other hand, may be called the multiple-shaft outdoor system. There is a soil-pipe which, according to the Model By-laws, must be outside the building and which receives water closet wastes only, and in addition to this one or more waste pipes, usually outside the building, receiving discharges from sinks, basins, baths, and other fixtures. The latter waste pipes discharge into or over one or more trapped yard drainage gullies which, under the combined system of sewerage, may receive also rain water from the roof. The discharge of liquid wastes through the medium of a yard-drainage gully is based upon the supposed necessity of establishing an " air-break " between the interior of the house and the outside drain and is apparently a universal feature of English house drainage. The drains leading from the gullies and the soil-pipe respectively are connected to the external main drain, which, in turn, is partially interrupted by an intercepting trap—an inverted siphon on the line of drain —furnished on the upper (house) side with a fresh-air inlet protected by a suitable surface grating. Under the Model By-laws, the " interceptor " must be placed within the curtilage of the premises served ; that is to say, it cannot be placed under the adjacent street sidewalk. In some cases, the interceptor is placed at the bottom of a manhole, to facilitate access.

In America there is sometimes a main trap on the house drain and sometimes a fresh-air inlet as well, but the tendency is towards the omission of both, thus giving a free run from all fixtures to the street sewer and a free circulation of air between the street sewer and the open roof terminal. Both in England and America fixtures are always trapped and sometimes back-vented, but individual venting seems to be carried on more extensively in America than in England.

In America the separate system of sewers is becoming more and more the rule, and it is common for the roof water to be kept separate and conveyed either to the street surface-water conduit or to a cistern in the yard, the water closet and other wastes being combined and carried to the sanitary sewer. In the larger cities having older sewers, the combined system is still in use.

As to materials, it would appear that in England the house drain is often made of earthenware pipe (called in America tile pipe or clay pipe), while in America it is more often made of cast iron. Lead has largely been abandoned for soil pipes in America—cast iron being chiefly used—but the former metal is still used in England.

In England the wastes from fixtures are carried out of the house as speedily as possible, a method consistent with the greater use of earthen pipe. In America the extensive use of cast-iron pipe has contributed to the adoption of more direct lines from the base of the vertical soil-pipe to the sewer, whether the former be inside or outside the house. To put it in another way, the drains in America run in and under the house; in England they run out and around the house.

Taking the Model By-laws for New Urban Houses (Ministry of Health, Model By-laws, Series IV) as representing the highest grade of British plumbing requirements, a few detailed comparisons with American practice will now be made.

Sec. 62 (1) requires that drains shall be of "*good sound pipes formed of glazed stoneware, heavy cast-iron or other equally suitable material.*" In America earthenware pipe is not usually permitted inside the building, although in some of the middle western states its use for house drains is allowed. Cast-iron is commonly used inside buildings and earthenware pipe outside.

Sec. 62 (2) requires *a minimum internal diameter of four inches*, if sewage is to be conveyed. This is the common size in America, but the Department of Commerce Committee found that a 3-inch pipe is large enough for the vertical part of the soil pipe. The tendency in the past has been to make the vertical stack too large and the horizontal house drain too small. This section also requires a "proper fall." In America the minimum slope is commonly stated as $\frac{1}{4}$-inch per foot, an example of the greater detail in the American codes.

Sec. 62 (5) requires that *drains shall not "pass under any building, except any other mode of construction is impractical."* This requirement is rarely, if ever, found in American codes.

Section 62 (6) requires *all inlets, except for ventilation, to be trapped.* The same result is obtained in America by requiring that all fixture outlets (i.e., outlets from fittings) be trapped. There is some reason to think that a greater depth of seal is a feature of American traps, this being facilitated by the more abundant supply of water used.

Sec. 63 requires on every main drain "*an efficient trap in a suitable position in every such drain,*" this being the "interceptor" referred to above. Formerly this had to be placed "at a point as distant as may be practicable" from such building. In America what is known as the "running trap" or the "main trap" is sometimes required, but it is placed in or near the building, usually in the basement or cellar. There is a strong tendency towards the omission of the running trap, some codes actually prohibiting it. The Department of Commerce Committee recommends its omission except in special cases.

Sec. 65 (1) requires *a fresh air inlet near the ground and a roof extension of the stack at least* 10 *feet in height.* In America the roof-extension is required, though not as high as 10 feet. The fresh air inlet, though once common, is rapidly going out of use along with the running trap.

Sec. 66 *prohibits any inlet to drain, except inlets from water closet*

apparatus or slop sinks, to be made within the building. In America such connections are almost always inside, because the vertical pipes, whether used as soil pipes or as separate conveyors of liquid wastes (as in large buildings), are themselves inside the building.

Sec. 66 requires that "*the waste pipe from every bath, sink . . . or lavatory . . . be properly trapped, and taken through an external wall . . . to discharge in the open air over a channel leading to a trapped gully . . .* etc." This requirement, already referred to as establishing the "air-break system," marks the chief difference between English and American plumbing. In America, contrary to this practice, all wastes may be carried indoors to the same vertical soil pipe which receives the water closet wastes, and this is the general practice.

Turning now to the Model Code of the United States Department of Commerce, a few of the requirements now the subject of controversy in America may be mentioned. Reference has already been made to the house trap and the 3-inch vertical pipe and the decision of the Committee has been stated.

The Code prescribes that every fixture shall be trapped, singly or in specified groups, and every part amply protected against losing its seal by back pressure, aspiration, or siphonage. This does not mean, however, that every individual trap must have its own particular vent pipe. At present, it is true, many codes require such individual venting, a practice strongly favoured by the labour unions, but by few others.

Unvented horizontal drains are limited to a length of five feet—a figure reached after much discussion. At present the limits, as stated by different codes, vary from 2 to 30 feet. The reason for limiting the length is to provide circulation of air and to reduce the danger of stoppage and corrosion. The decision in favour of a five-foot limit was based in part on researches made in the Laboratory of Sanitary Engineering at Harvard University.

The so-called "non-siphon," "anti-siphon," or "re-sealing" traps, of which there are many on the market, are not favoured as standard practice, but should not be debarred by regulation. This detail has been a bone of contention in recent years.

The so-called "flush valve," or pressure system of flushing water closets (in place of a flush tank), is not favoured for small dwelling houses, because of the large water supply pipe required to give the necessary rate of flow. But flush-valves are much used in office buildings and in the many-storeyed apartment buildings (flats) having similar constructional features.

The foregoing are some of the more important matters which have been under discussion in America in recent years and upon which the Committee passed judgment. It will be observed that some of them would not apply to the English system of plumbing.

It remains to be seen, of course, whether the proposed Model Code of the United States Department of Commerce Committee will be followed by the various States. It will take several years, at the least, to secure the necessary legislation and bring uniformity out of the present chaos.

The question may now be raised whether there are climatic and other differences between England and America which justify the divergence between the two systems of house drainage. The winter climate is certainly responsible for putting all plumbing pipes indoors in the northern part of the United States and Canada, in which connection it may be said that Canadian practice agrees with American rather than with English. Neither outdoor intercepting traps, "air-break" waste discharges, nor exposed soil pipes are suitable for cold winters and deep snows. The use of water per head is much less in England than in America, and the volume of water used for flushing water closets is far short of the 4 to $4\frac{1}{2}$ imperial gallons which is the American average flush. The smaller volumes of water make the English sewage more concentrated, and the resulting intensity of odours in the sewer and drain air may demand more effective protection of the houses against it.

It is most likely, however, that tradition rather than reason is responsible for the chief differences. In the writer's opinion, the English system errs in not permitting the greater use of a single stack (vertical pipe) and in attaching an exaggerated importance to the "interceptor"; the American system errs in overdeveloping the extensive and complicated venting system and especially in having too many individual back vents. American plumbing laws err also in making too much of the licence system and in having too detailed codes. It would be well if a real distinction could be made between governmental requirements, justifiable under the police power, and standards of acceptable practice set up as models rather than as laws and followed by custom instead of by compulsion. The Department of Commerce Committee has endeavoured to make some such distinction by drawing up, first, a set of Basic Plumbing Principles, twenty in number, setting forth the results aimed at but not telling how they are to be secured, and, second, a Model Plumbing Code, of 153 sections, which, if followed, will automatically yield the results defined in these basic principles. At present the plumbing codes in the older eastern States of America are relatively short; those in the newer western States are long and partake of the nature of specifications. The new Model Code is intermediate in length between the two.

The plumbing laws in both countries are seriously to be criticised for not having thrown off sooner the incubus of the antiquated and scientifically discredited sewer-gas theory of disease transmission. In 1875, when plumbing regulations were first systematised in England, and in the early eighties, when the first American regulations were established, the sewer-gas theory dominated the field. But while the modern science of bacteriology has upset those prevailing ideas, it will not do to go to the extremes advocated by some bacteriologists and say that there is no relation between plumbing and health. To quote from the Department of Commerce report:

> "The air in sewers and drains often contains gases resulting from the decomposition of excreta, soap, fats, and other wastes, together with gases from mineral oils which may come from garages, streets, and

industrial establishments. Illuminating gas may also find its way into sewers through leakage. Among these gases may be found methane, sulphuretted hydrogen, and carbonic oxide. In large amounts those gases are poisonous to the human system, and there are physiological objections to breathing them even in small quantities. Hence the air of sewers or drains should be kept from entering buildings intended for human habitation or occupancy by the use of proper plumbing installations and by suitable ventilation of the rooms or compartments in which the plumbing fixtures are located. The smell of these gases and other emanations from decomposing organic matter is naturally repugnant to human beings. It not only offends the sensibilities but may produce shallow breathing, headache and even nausea. . . .

"Bacteriologists have shown by experiment that, while sewage often contains disease-producing bacteria derived from human excreta and body wastes, these bacteria are rarely found in the air which escapes from sewers and drains. Hence it has been argued by some that escaping sewer air has no influence on health. We do not agree with this conclusion. Health may be influenced by factors which do not cause specific diseases, for there are chemical and physiological as well as bacteriological factors involved. The investigations thus far made by bacteriologists should be considered to be merely a beginning of larger and more complete investigations which will doubtless be made as the science of bacteriology advances. Until further light on this somewhat obscure subject has been obtained, therefore, the committee is of the opinion that the escape of sewer air from the house drainage system, at frequent intervals, or in considerable quantities, threatens the health of the building's occupants.

"This whole matter has a quantitative as well as a qualitative aspect. The temporary losses of water seal in traps, which rarely occur and which are immediately replaced, do not involve any great danger to the health of the occupants, for in many cases the final drainage from the fixture will renew the seal within a short time; but where a loss of seal is likely to be of frequent occurrence and not readily replaced, or where breaks in the system admit sewer air continually to a building, the health of the occupants is subject to the dangers heretofore described."

Time will not permit a discussion of detailed plumbing practice. A study of English and American trade catalogues of plumbing supplies indicates that in England there is far greater complexity in fittings than in America, where some progress has been made towards standardisation and the elimination of unnecessary fittings. For example, in America soil-pipe is cast in one length only, i.e., five feet; in England it is made in lengths of 9, 8, 4, 3, and 2 feet and 21, 18, 15, 12, 9 and 6 inches. In England bends are made with angles of 90°, 95°, 100°, 112.5°, 120°, 135°, 145°, 157.5°, 170°, with radii long and short. In America the common fittings for bends are $\frac{1}{4}$, with regular, long and short sweeps, $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{8}$ and $\frac{1}{16}$. This single instance is typical.

The writer wishes to bring to the attention of his English colleagues the efforts which are being made in America—notably by Secretary Hoover of the United States Department of Commerce—to bring about simplified practice in many lines of business, to standardise the dimensions of things in daily use, and to do away with the multiplicity of seldom-used articles which are found in so many of the building trades. This movement is one which appeals to the practical sense of those interested in manufacturing, transporting, selling, and using plumbing supplies, and which in the course of time is likely materially to reduce costs of construction.

While standardisation and simplified practice will tend to save materials, freight and storage charges, breakage, and overhead expenses, the Department of Commerce Committee took the position that these benefits should be brought about by agreement and not by law. But, in the present chaotic state of plumbing legislation, agreements between manufacturer, plumber, and householder cannot be secured. One of the greatest advantages to be derived, therefore, from the general adoption of the Model Code is that it will pave the way for standardisation.

If the ideas of the Department of Commerce Committee are carried out, the resulting benefits will be beneficially distributed. House owners will gain by having better plumbing, lower first costs, and fewer repair bills. Manufacturers will gain by producing larger volumes of standardised products. Plumbers will gain by putting plumbing into more houses and by establishing better relations with the public. Simpler plumbing will help to conserve the nation's metals, especially iron, and will save transportation. Better plumbing will prevent the waste of water and bills for repairs. Health will be amply protected by adequate factors of safety and enhanced by a more liberal use of water.

The world has paid dearly for its false theories. The sewer-gas theory of disease transmission was largely false. It has led both England and America to waste enormous sums of money on plumbing devices to protect against exaggerated dangers. It is time to revise our methods and base them on modern scientific knowledge instead of on tradition. To do this more attention must be given to science as applied to drainage systems. Even then, however, it must be remembered that our present day science is not the last word, and that to abandon all protections against sewer air would be folly. It will be well to follow the injunction, "When you go back, stop half way."

DISCUSSION.

Dr. G. S. Coleman (University of Manchester) said that, as head of a department having a very large number of students in this subject, he heard a variety of opinions on the advisability of inside drainage.

He would first of all like to know whether in America it was customary for the water supply authorities to insist on the disconnection of sanitary appliances by means of waste-water prevention cisterns. This was compulsory in this country, and was largely due to the wish to save water, apart from the idea of preventing pollution of the drinking supplies.

It was not the speaker's intention to re-open the old controversy as to "when was a drain not a drain?" but he would like to point out to those from abroad that we in this country are accustomed to confine the term "drain" to that part of the system connecting the house to the public channel. When the drain passed outside the property boundary it became a "sewer," and the cost of its repair fell on the sanitary authority.

As regards the single stack, we still in this country kept rigidly to the provision of separate pipes for human waste and washing water, but the rule had been recently broken by the Government on their housing schemes on the side of economy. Personally, the speaker saw no valid reason why such a rule should be strictly adhered to, provided the work was properly carried out.

Probably the principal reason why inside piping was common in the United States and Canada was on account of the greater range of temperature in those countries. If placed on the outside of the house, it would probably mean that the pipes would be frozen up in winter and cause nuisance during the summer owing to more rapid decomposition of solids.

He was interested to hear that lead soil-pipes had been largely abandoned in the States. This was not the case here, where lead was frequently insisted upon for inside work. The reason appeared to be that the material was smoother than iron, was non-corrosive, could be easily bent to any special shape, and could be more thoroughly jointed. In this case only the so-called "wiped" joint would be allowed.

In this country the licensing of plumbers was not compulsory, but in the larger towns a large proportion of the apprentices were in the habit of attending classes at the technical schools and passing certain public examinations of a high practical and theoretical standard. In many cases the firms paid the necessary fees and allowed the students to attend the courses, when held in the day-time, without any pecuniary loss.

He would like to take the opportunity of saying how much they owed to the public spirit of the craft. The masters were always willing to support any scheme for promoting knowledge of the work, and just lately the manufacturers had arranged to provide free of charge any lead required in the laboratories and workshops, the only cost to the schools being that of carting. The boys themselves were on the whole very keen, and were anxious to obtain the school or other certificates.

As regards the carriage of disease germs from one house to another by means of the public sewer, it was now common knowledge that such carriage was extremely rare. Hence the provision of a disconnecting trap or chamber was not now nearly so obviously necessary as it had formerly been thought to be. The germs could only be carried through the air or dust, and such dust was largely absent in drains and sewers. Germs carrying infectious disease were delicate and were very liable to die through the damp, to be drowned, smothered in the silt, or attacked by hostile organisms who made their home in the channels.

The speaker had the great privilege some years ago of assisting the late Professor Delépine of the Public Health Laboratory, Manchester, in some elaborate experiments on ventilation. These experiments were made to determine, amongst other things, the number of disease germs present in sewer air as against ordinary air in the street. The conclusion arrived at was that very few such organisms existed. In many cases not a single organism of any kind was found, whereas millions existed in the same volume in the open air. In the speaker's opinion the only danger from ordinary sewer air was either the presence of noxious chemical gases or the debilitating effect of offensive fumes which, when inhaled habitually, would predispose to certain throat and lung diseases.

In the speaker's opinion disconnecting traps were more often a source of nuisance than a prevention. They were generally difficult to ventilate without causing objectionable smells, they were frequently blocked, the inspection caps were either missing or broken, and they were no deterrent to rats. He considered that the Departmental Committee's report practically proved that they were somewhat of a delusion, and many other countries had either abandoned or prohibited them. Many borough engineers in this country had given up insisting on them in spite of the by-laws under which they were supposed to work.

In Manchester the Health Department issued what he considered an admirable set of instructions to builders, which was copiously illustrated to comply with the by-laws founded on the local Acts. These instructions could be obtained from the Director of the House Drainage Department.

Mr. Walter Scott (Vice-President Associated Master Plumbers) agreed with Professor Whipple that it was high time steps were taken to go into a deeper study of the problem, with a view to evolving a model code of by-laws, in the same way as the Ministry of Health had recently evolved a model code of water regulations. For the last eight or nine months a technical sub-committee, of the Statutory Committee set up to advise the Minister of Health on water regulations, had been sitting at the Ministry, and had formulated a model code of water regulations, which had been approved, and would be in print very shortly. There was another sub-committee to deal with by-laws. They would not be compulsory, but model, to enable Local Authorities to base their own by-laws upon them. Such model by-laws were necessary in connection

with sanitation. They did not want fixed by-laws for every district in the country, but a model specification, and they wanted plumbers qualified to carry them out. As to the registration and licensing of plumbers, he was somewhat taken aback to find that the licensing system in America was not compulsory. In England the registration movement was growing apace, and the Worshipful Company of Plumbers had decided to get into touch with plumbers in the Dominions and Colonies and in the United States in an effort to get one universal system of registration of plumbers for the general uplifting of the trade. Though we in this country did not want a really stiff and hard-set code of by-laws, he felt that we did want compulsory registration and licensing of plumbers. One very great mistake made in this country was that plumbing was placed in the hands of incompetent people, or people not so competent as they might be. There were plenty of qualified plumbers in this country. As to the three-inch soil pipe, the late Mr. S. Stevens Hellyer had put up a three-inch pipe thirty or forty years ago, and after it had been in use for some years, had found that it was cleaner inside than any other soil pipe. Soil pipes were too strong, in his (Mr. Scott's) opinion, but he did not agree with the suggestion in the paper that drains were somewhat too small. He knew, from experience, that a four-inch drain was very much more satisfactory for many buildings than a six-inch drain. They were kept cleaner by the discharges through them, and there was less liability of stoppage. He had often thought that if it ever came about that a committee was set up to go into the question of a new code of sanitary by-laws and regulations, one might suggest that it was unnecessary to have so many vertical stacks as we have. He did not see why each floor in a large building should not have a drain to itself, and a main stack put on its own sewer. He disagreed from Dr. Coleman that a pipe became a drain when it entered the ground. Many drains were in sight in basements. As to the multiplication of pipes, that was a question which would have to be carefully thought out with regard to ventilation, because we had always to take steps to preserve the water seal of traps. With regard to soil pipes inside and outside buildings, the London County Council had recently passed a by-law permitting iron soil pipes inside houses. In this country an iron soil pipe was not suitable to be fixed inside a building; the only one permitted should be lead. His reason for saying that was that he had found in nearly every case where there was an iron pipe, it became stopped up by rust at the bend. He had found, when taking down soil pipes, that the insides were rusty, and he attributed it to the fact that the coating, which was supposed to be Dr. Angus Smith's solution, was not carried out to Smith's specification. The coating must be done by special apparatus. Dealing further with the question of iron soil pipes, and their unsuitability inside buildings, he pointed out that, inside a building, the thickness of the wall was reduced at each floor. If they put an iron soil pipe inside a building in London, they must, of necessity, have bends above the top fitting, to get over the breaks in the wall, and the stoppage would occur

at those bends, especially when the rust from that part of the pipe which was above the bend fell into the bend. In urging again the necessity for research in connection with sanitary matters, Mr. Scott expressed regret that there was practically no support forthcoming from official quarters. Some years ago he had attempted to get a grant from one of the county councils in this country for the purpose of carrying out research, in conjunction with a scientific friend, from both a scientific and a practical point of view, but the particular county council had offered a very inadequate sum. If some association could be persuaded to put up the money for tests to be carried out, he felt sure they would be able to come to useful conclusions; also, there might be some collaboration with our colleagues in America. It would be valuable in both countries.

Dealing with interceptors, Mr. Scott considered that a good deal of trouble arose through their use; they caused more trouble, especially in open manholes, than there would be if there were no interceptors. At one time he had been called in to deal with a case in which some sewage was floating about in the cellar, and had found an interceptor at the bottom of a manhole, about twelve to fourteen feet deep, and a tidal valve at the side of it, into which was connected a subsoil drain. After he had got the interceptor cleared, the water had come back through the joints in the brickwork into the manhole, showing that the interceptor had been the cause of the flooding. If an interceptor was to be fixed in such a case, and he agreed with the provision, it should be of a sealed type, so that there was no possibility of water getting from it into the soil around the house or even filling a large manhole. As to standardisation, Mr. Scott said we did not want it in this country at the moment; it would destroy initiative, and he pointed out that many of the best fittings used in this country were constructed as the result of individual effort and excellence. Moreover, under present conditions, we should be flooded with foreign-made goods, which we did not want, and therefore, standardisation should be postponed.

Mr. H. Alfred Roechling, Westminster, writes:—Prof. George C. Whipple's paper is so important, that I should like to make a few further observations, which owing to the necessarily restricted time I was unable to make in the general discussion.

As I know nothing of my own knowledge of American house drainage practice I must confine myself to the English practice, with which both in theory and practice I am well acquainted, and here too I can only deal with leading considerations and not with detail.

Prof. Whipple states his general conclusions in the last paragraph of his paper and these I will summarise in the following order:

1. Enormous sums of money have been wasted in plumbing fads.
2. The sewer gas theory of disease transmission is largely false.
3. The English house drainage practice is not based on modern scientific knowledge, but on tradition instead, and

4. The intercepting (disconnecting or running) trap is not necessary, except in special cases and should be omitted (p. 265, Sec. 53).

With these views I totally disagree. English house drainage practice is based on sound scientific principles evolved out of previous failures; it is not wasteful, it was the first in the field, and it occupies to-day the foremost place or, at any rate, is second to none.

In my opinion sanitary engineering is the science of utilising nature's laws in the construction of works primarily for the benefit of the health of man and, secondarily, for his convenience and comfort. It is a branch of the large collective science of "preventive medicine," as it comes to be understood to-day, in which the sanitary engineer has a large number of scientific co-workers, who unfortunately frequently work in almost watertight compartments without "liaison officers." Preventive medicine has called forth sanitary engineering, and if the latter is taken out of this frame and looked upon by itself, erroneous conclusions are easily formed.

The chief aim of sanitary engineering is to prevent disease, that is its *raison d'être*, and if it does not do that, it is a lamentable failure. But in order to prevent disease sanitary engineering must create such conditions of life as will maintain always at their best the natural defensive or resisting powers of the constitution—whatever they are—so that when disease attacks it—no matter what the disease is, infectious or non-infectious according to our present notions—it is able to hold its own, throw off the attack and emerge victoriously. To enable the constitution to resist the beginnings of disease, to prevent in fact all disease-predisposing influences is, therefore, the prime function of the sanitary engineer, and he should never construct his works in such a manner that, in our present very limited state of knowledge of nature's laws, is liable to the least suspicion in this respect. Of the two—the host and the parasite—if they are not of equal importance, the former is probably the more important, and it seems sounder strategy to fortify the resistant body of the patient than to attempt a frontal attack against an enemy of unknown strength. Prevention is always better than cure, even if the latter is at all possible.

Of engineering principles the sanitary engineer must, amongst others, always bear in mind the following. In any structure the weakest link must be capable to stand the strain to which it is subjected, and to be able to do so a factor of safety must be selected to provide for any contingency, over which the engineer has no control. Further, especially in health matters, security must not be sacrificed to economy, for the most efficient works are the cheapest in the long run.

The present English house drainage practice is the result of previous failures with their lamentable loss of life. Internal pipes concealed under floors and in wall plaster, bad plumbing and the total absence of traps, or traps of an unsuitable kind, led to these deplorable results. Sanitarians then evolved the principles which guide us to-day, viz.,

the speedy and innocuous removal of all waste liquids from the interior of our houses and the prevention—by aerial disconnection—of the entrance of foul air or gases out of the street sewer and the house drains into them. These principles are based upon scientific knowledge and not on fads.

In street sewers foul gases or air cannot be avoided. A large network of street sewers must be looked upon as an immense chemical retort, in which many opportunities exist—through interaction—for the formation of new combinations, so that no guarantee can be given that sewage at one time or other may not produce in a startling manner poisonous or other injurious effects. I remember a tempting repast in a large dome-shaped chamber near the mouth of a large new storm outfall, not yet in use, two miles below the town, being completely spoiled by an abominable stench travelling down from the town, which caused us all to beat a hasty retreat before we had tasted the dainties.

In a house drainage system these conditions do not exist, and the air therein can be, and is, to my own extensive knowledge, perfectly sweet, provided it is properly designed, constructed and maintained—very reasonable conditions—and is left at no time to the tender mercies of an inefficient bricklayer!

Nobody who professes to know anything about the matter, can possibly recommend a return to the old condition of things such as internal pipes, and as regards the influence of frost on outside pipes, if there is nothing in them that can freeze, nothing will freeze.

I have no space to deal with details of a mechanical nature, but I am not in favour of deep seal traps generally, as they interfere too much with the free flow of sewage. In large installations a greater simplicity is now and then advisable, but speaking generally I am not aware that our plumbers are wasting enormous sums in mere fads. The omission of the disconnecting trap, which in my opinion is most inadvisable, will at best only save a few shillings and has never been suggested on that account in this country.

I attach the greatest importance to good installations properly designed, carried out and maintained, as without these quite reasonable conditions being fulfilled no house drainage system, and indeed no apparatus of any kind, can give good working results for long.

Unfortunately we are not yet in a position to assign for every specific effect its specific cause and this is to some extent due to our still very imperfect methods of investigation. It has been shown that the sense of smell in man is at least a million times more delicate than the most refined of physical tests, such as the spectroscope, and probably a thousand million times more delicate than the most refined tests of bacteriology. The elucidation of the laws of nature is a very complicated and laborious process, as she seems very loath to part with her secrets.

Concerning the influence of sewer air or gas upon health we are all agreed that it is injurious to it, and that it must be kept at all costs out of our houses. This is, after all, the main point, and differences as to

the nature and degree of injuriousness are only matters of detail that do not affect the principle.

That the air or gas contained in street sewers can at times kill instantaneously, has been proved by many sad accidents.

The theory that sewer air or gas *per se* can produce such infectious diseases as typhoid fever or diphtheria has so far not been proved, but in connection with this, we must bear in mind, that to find a typhoid bacillus in sewer air is like looking for a needle in a haystack, that our methods of investigation are still very imperfect, and that with improved methods different results may be obtained. In connection with this it must further be remembered that Laws and Andrewes had the greatest difficulty in finding the typhoid bacillus in the sewage from the typhoid fever block of the Eastern Hospital at Homerton, and that typhoid epidemics have been attributed to a water supply in which no typhoid bacilli were found. Negative evidence must not be mistaken for positive one.

The influence, on which I think we are all agreed, is the disease-predisposing influence of sewer air, an indirect one. This is the influence by which the general vitality of the individual is lowered, rendering his constitution an easy prey to the attack of disease. But this influence is of vastly greater importance than the direct specific disease influence, as it is at the beginning of most, if not all diseases, that it is felt most acutely. The beginning of disease is practically an unknown and uncharted world, and it behoves us all to treat this influence most seriously, as I have previously pointed out.

A statement that the sewer-gas theory of disease transmission is largely false is, therefore, apt to be totally misunderstood and should be put as follows. Whilst the direct transmission of specific disease by sewer air or gas has thus far not been proved, there is ample evidence of its injurious character on health either directly—instantaneous death through asphyxia—or indirectly by lowering the vitality and thus predisposing the individual to attacks of almost any kind of disease.

Bearing this in mind, the contention that our house-drainage practice is not based on modern scientific knowledge but upon tradition, seems to me to be also incorrect. It cannot be more scientific to consider only that portion of the influence of sewer air upon health which has not been proved, and to neglect all the other influences, than, whilst admitting this failure thus far, to consider the subject in all its aspects and to guard zealously against any injury to health. I think the former position is an unscientific one. True science is always modest, is aware of its limitations and is never dogmatic on doubtful points ; it is never shortsighted.

The opinion that the disconnecting trap is not necessary and can be safely omitted, except in special cases—an idea which I believe originated in Germany—has lately spread to some extent in this country, and has been rendered plausible by the alleged physical disadvantages of the trap. In my opinion such a view is not justified by facts, as I will endeavour to show.

In the propaganda for this view much use has been made of a report issued in 1912 by the late Local Government Board, now the Ministry of Health. But before using it a correction of a serious error in it will have to be made, which practically changes its aspect completely. How this error came to be overlooked I cannot say.

It is stated in the Report that nearly one trap in every four examined was found blocked, whereas the figures given in it clearly prove that only about one in every nine traps examined was found unsatisfactory. The Report, therefore, more than doubles the failures observed.

Taking only the first series of traps examined as being the most important and affording direct and clear evidence, it follows from the figures given, that out of every hundred traps examined about ninety-three acted perfectly satisfactorily, so that the chances in favour of the trap are over twelve to one. This is, however, well on the road to dead certainty, that a properly constructed, fixed and used trap—all quite reasonable requirements—will answer perfectly satisfactorily. If for so small a percentage of failures we have to condemn the trap, we shall have to scrap every apparatus made. For no apparatus is nor can be made that—however improper its use—will never get out of order or can be used in perpetuity without an occasional inspection.

I ought also to point out that it is quite evident that purely local faults—improper construction, fixing and use—are largely responsible for the failures observed, for if in one case only about one trap out of every seventy examined was found faulty, it stands to reason that similar good results might have been obtained in the other cases, if the same care and supervision had been employed.

Again the number of traps examined is only an infinitesimal percentage of all the traps in use in this country, and is certainly far too small to admit of generally applicable conclusions.

The tests as to the matters retained in the trap are quite inconclusive, as they have not been made under the usual working conditions, a solitary two gallon w.c. flush having been used in most cases. But in practice the quantity of water passing through the trap is much larger, and I have shown elsewhere, that the contents of an ordinary 4-inch trap are completely renewed 104 times in every 24 hours in the case of one-family dwelling-houses.

It is the expressed aim of the disconnecting trap to prevent the free ventilation of the street sewer through the house drain. It forms an effective barrier against the entrance of sewer gas from the street sewer and is not liable to be forced by back pressure of gas from it, as the Repor clearly shews. But even without the trap no guarantee for such system of ventilation can be given, as is clearly pointed out in the Report, so that the opponents of the trap cannot use this argument as in their favour.

Again, in the absence of this trap, there is no guarantee against the free entry of sewer air or gas into the interior of dwelling-houses let on the "flat" system, as the water seal of the internal traps in a flat

or flats standing empty may evaporate. I have heard of a case where this contingency was sought to be guarded against by a public inspector, going round with lumps of clay in his pocket to seal down the traps. When a number of houses are drained by one main drain, a similar condition of things may arise.

Making the necessary correction in that part dealing with the trap's liability to blockage, I am of opinion that the evidence adduced in the Report is distinctly in favour of the retention of the trap.

The position of the opponents of the trap is, in my opinion, a short-sighted, illogical and unstrategical one, based to a large extent on an incomplete understanding of the subject. They admit that sewer air or gas should be kept out of our houses, but they surrender the first line of defence against such entrance owing to the alleged liability of the trap to blockage and to its preventing the free ventilation of the street sewers through the house drains, for which there can be no guarantee whatever.

In my opinion the trap forms the first line of defence against sewer air or gas entrance; it forms a necessary factor of safety, it can be relied on to act properly under reasonable conditions, and its cost is comparatively trifling. Why, then, should it be omitted? If this main trap is not necessary, surely the only logical result of such a contention is that all other secondary traps are likewise unnecessary!

I do not know whether similar considerations as I have advanced have guided the Ministry of Health, but it appears to me that they have not taken much notice of this Report. For in their Model By-laws, Series IV., IVc. and IVa., published in May last, the Ministry still insist on the retention of the trap. All they have done is to give Local Authorities a provisional option to omit the trap on special application, where the house drain is connected with a public sewer in the street; but where it is connected with a cesspit they still insist in full on the insertion of the trap. In other words the Ministry still believe in the efficacy of the trap.

Until we can assign to every specific effect its specific cause, we are bound to be extremely careful in all matters relating to private and public health and not to run any risks concerning it. We probably stand to-day only on the threshold of the knowledge of health and disease, of life and death, and before us is a vast unknown tract of territory, which has only been explored on its circumference, but into which no solitary traveller has yet penetrated. Therefore it behoves all who are interested in matters of private and public health always to bear fully in mind that health is the greatest blessing man enjoys, far surpassing material wealth, and that when once it has escaped our grasp life becomes a weary burden and a drudgery.

OBSERVATIONS ON OPERATING EXPERIENCES WITH CANADIAN SEWAGE DISPOSAL PLANTS.

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INTRODUCTION.

The present paper is limited to the writer's experience in the Province of Ontario. The provincial situation is, however, quite typical of that of the rest of the Dominion of Canada, and, as a matter of fact, the majority of the total plants operate in Ontario.

Sewage disposal in Ontario has quite an interesting history, and for the purpose of this paper, it is of interest to point out that the sewage disposal enterprises undertaken by municipalities prior to 1913 were under the direct supervision of a provincial board of health, composed solely of medical practitioners.

Judging from the problems confronting the Province at this date, it may be expected that the sewage disposal plants installed prior to 1913 were installed at the express instruction of the Board, and without expert advice as to the most suitable types for the local requirements.

In all, some forty-two municipal plants are in operation, three of which perform no useful purpose ; seven protect bathing beaches or lake front property from gross solids ; nine were designed to protect small streams from complete breakdown ; the balance, some twenty-three in all, exist for sentimental reasons, largely through the initiative of the Board and partly because the local consulting engineer had sufficient force of character to include sewage disposal works in his main drainage scheme.

REMOVAL OF SOLIDS.

Provision for the removal of solids in Ontario plants exhibits numerous examples of sedimentation basins, Cameron septic tanks, chemical precipitation plants and Imhoff tanks, with several modifications in the manner of arrangement, and continuous-flow retention for activated sludge treatment.

OXIDATION TREATMENT.

The oxidation treatment includes examples of broad irrigation, intermittent filtration through sand ; biological sprinkling filters with various types of application (i.e., revolving arms, fixed sprays, and travelling distributors of the wheel type) ; with different types of media, that is to say, broken stone, gravel, coke, of different sizes of aggregate, and brush mattresses.

Activated sludge is represented by seven municipal installations with some eight others under construction.

The figures above quoted do not include a number of institutional plants, which are as diverse as those referred to.

DISINFECTION.

The disinfectant commonly employed is free chlorine. Chloride of lime is used generally in the smaller plants and without much success on account of its variable strength. In the larger installations liquid chlorine is being advocated, but owing to the very considerable cost, its introduction is slow. The city of Toronto operated a chloride of lime plant for several years, and then abandoned it in favour of more intensive water treatment.

OPERATING EXPERIENCE.

The operating experience which is most common to all Canadian plants is neglect, which is not surprising, when of the total number of plants only some sixteen have been installed for a definite purpose, and under pressure from adjoining municipalities, or owners of riparian rights on the streams affected.

Of these plants about 60 per cent. are receiving a reasonable degree of supervision, and all are capable of operating in a thoroughly satisfactory manner.

The plants in a general way suffer from the operating experience common to their respective types, all the world over. *Climatic conditions* in Ontario, which in winter are quite severe, do not have any appreciable effect on any of the processes, except that of sprinkling filters, which should be covered in order to prevent freezing of the spray during the winter. Plants of this type have been operated in the open in Ontario without any serious difficulty other than lowering efficiency, due to loss of surface from frozen mounds ; the sewage in all instances being warm enough to prevent freezing of the biological filters.

It has been our observation that ponding on sprinkling filters is invariably associated with some condition in the settling tanks which promotes the seeding of the sewage going to the sprinklers with the fungus whose growth and decay occasions the ponds.

There is no record of organisms or chemicals being applied to the biological beds to control ponding in Ontario. This nuisance has not been sufficiently serious in Ontario plants to warrant correction. Experimentally, the conditions promoting ponding can be readily induced in this climate.

Final sedimentation of the effluent from sprinkling filters was not incorporated in the earlier designs, i.e., prior to 1913, and in consequence, the streams had to receive the unloading of the filters, which very largely nullified the result of the earlier sewage treatment plants of this type.

ACTIVATED SLUDGE.

Several of the activated sludge plants have operated in the open during rather severe winters without difficulty, and most of the plants now under design will be of the open type with the machinery and valves under cover.

Fortunately for the activated sludge treatment in Ontario, the acid industrial wastes have been associated with waters of sufficient hardness to nullify the acid after dilution. There is no instance of an acid municipal sewage requiring treatment. The activated sludge process for the combined municipal sewage has been uniformly successful from the treatment point of view, wherever installed.

The usual early difficulties were encountered with the settling tanks accumulating sludge and belching. This has been overcome very largely by increasing the number of air lifts and by structural changes.

The present trend of practice is toward using shallow Dorr clarifiers with simple transverse flow, and away from the use of multiple deep sedimentation tanks, with sharp inclines.

SLUDGE DISPOSAL.

The sludge from the septic tanks seems to offer the least difficulty in drying. The Imhoff sludge is handled without difficulty. At Hamilton chemically precipitated sludge (lime method) is being pressed, and has no local market. At Toronto attempts at digestion of settled sludge in lagoons is proceeding with a minimum amount of nuisance, provided the surfaces of the lagoons are protected by straw or other mattresses to prevent the contact of air currents with the evil smelling gases. During the colder months a certain amount of auxiliary heat is necessary for the digestion tanks.

The problem of disposal of activated sludge has been satisfactorily met by lagooning and maintaining several feet of supernatant liquor on the sludge, the resultant sludge after several months being almost identical with the stored Imhoff sludge in appearance and odour. The nitrogen content is lost during digestion, and the resultant sludge has no

value as fertiliser. Some of the smaller plants enjoy a local market for both Imhoff and activated sludge. At Brampton the activated sludge is entirely absorbed by a large florist, who mixes it with other composites.

EXPERIMENTAL WORK.

The Department of Health of the Province of Ontario operate an experimental station—probably the best equipped station on the continent, and with laboratory facilities similar to the old Lawrence, Mass., Station. This station, since 1913, is attached to the Engineering Division of the Department.

It is at this station that the various inspectors and engineers attached to the Department become more or less conversant with the limitations of the various types of equipment and processes.

PRESENT GOVERNMENT ATTITUDE *re* SEWAGE TREATMENT.

Sewage treatment other than plain sedimentation is never insisted upon as a part of a main drainage scheme, except there is evidence to show the stream's inability to receive untreated sewage, and there is some definite health hazard introduced in respect to bathing beaches or water fronts used for recreational purposes. In no instance is sewage allowed to be discharged, whether treated or otherwise, in such a position as directly to affect a municipal water supply, save when there is an adequate storage interval between the two points.

Initiative for sewage disposal is more or less a joint responsibility of the Government and owners of riparian rights, who can establish right of redress under Common Law.

The Department in the latter instance is invariably appealed to as arbitrator and imposes the degree of treatment which will satisfy, as seems meet, the contending interests ; its decision being final, with the provision that further action may be brought on the grounds of negligence in the operation of the works imposed.

STANDARD OF SEWAGE EFFLUENTS.

The Government has found it inadvisable to fix standards for sewage effluents. The area covered by the Province—(407,262 square miles)—is so large, and the situations are so diverse, both as to the size of the streams and as to their subsequent use, as to preclude any standard operating with even a minor degree of acceptance.

In respect to the international boundary waters between Canada and the United States, the treaty of 1909 provides, in the concluding paragraph of Article 4 :—

> "It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of the health or property on the other."

THE GREAT LAKES AND CONNECTING RIVERS.

Ontario is singularly fortunate in having most of the urban concentration of population on the Great Lakes and the connecting rivers of the St. Lawrence River Basin. These rivers and lakes are of a magnitude which do not call for oxidation processes, and the treatment of sewage naturally limits itself to the most economical types, necessary to eliminate æsthetic nuisances, and which permit of the periodic disinfection of sewage during the few months of the year when surface waters are warm enough to permit of bathing, and when general advantage is taken of them for recreational purposes.

In view of the fact that the Great Lakes and connecting rivers also serve as water supply for these, and adjoining cities, the question of sewage treatment is becoming more and more tied up with the local problem of maintaining satisfactory standards for water supplies.

The incentive for sewage treatment in many municipalities of the Great Lakes region comes from the local authority rather than from the provincial. This is also true of a number of the American cities, which are likewise situated on the Great Lakes, such as Cleveland, Chicago and Milwaukee.

With respect to other parts of the Province, small streams seldom serve as sources of water supply, except where adequate storage offers protection. The use of these small streams for sewage disposal, or to receive treated sewage suffers, however, from a very peculiar disadvantage, in that the minimum run-off for the year coincides very closely with the hottest season, and in situations where the water-sheds have been fairly well denuded of trees the problem is acute. Sewage treatment for towns, so situated, must involve complete oxidation processes in order to support the stream life during a very short season of the year, not as a rule exceeding three months.

In this regard, Ontario municipalities are situated not greatly different from Chicago, which labours under identically the same disadvantage. The Chicago drainage canal and its outlets heat up sufficiently in summer to make oxidation by dilution an impractical problem.

When complete oxidation is essential, the Department of Health has most sincerely directed municipal authorities' attention to the activated sludge process, since it offers a complete oxidation process at a reasonable capital expenditure.

Extensive research has been carried on with this process by the experimental station to determine how far it is possible to reduce the operating difficulties and maintenance charges. A cost as low as $14.00 per million gallons of sewage treated has been realised by one of the municipalities (Woodstock) when treating quantities in excess of a million gallons.

TABLE I.

ANNUAL COST PER MILLION IMPERIAL GALLONS TREATED—ACTIVATED SLUDGE METHOD—1923.

	Woodstock.	Brampton.	Timmins.	Guelph.
Labour	0.81	6.00	1.97	6.00
Power	3.20	3.50	1.55	3.45
Sludge disposal	0.09	—	2.96	1.15
Repairs and alterations ..	*4.75	—	*13.50	†0.92
Capital charges	10.20	8.20	12.00	10.00
Total, 1923	19.05	17.70	31.98	20.60
Deducted for extra labour	—	4.00	—	4.00
Deducted for plant changes charged as repairs ..	4.75	—	13.50	0.92
Anticipated annual cost ..	14.30	13.70	18.48	16.60

The disparity in labour costs appearing in Table I brings out two points, which are of particular interest.

At Brampton the municipality allows a man to put his full time on the disposal plant, finding employment for the man rather than attempting to operate the plant at a minimum cost.

At Guelph, the extra labour charge has been made necessary because the local engineer, who carried out the design, took too many liberties and thereby introduced complications. The lower section of the sedimentation tank was modified from the original sketch, and gave difficulty with the sludge removal. The compressors were of the water-cooled type, and the liquor in the activation tanks was circulated for this purpose. The rack screens in connection with the detritus tank were also spaced too close. Check valves were not provided on the connection to the several compressors. These several deficiencies in an otherwise well-arranged plant necessitated the employment of extra labour to provide against interruption.

In the past year these various matters have been rectified and it is anticipated that the labour charge can be more than cut in two.

The item listed as repairs in connection with Woodstock and the Timmins plant provides for the replacement of the original filtros plates, cemented in concrete channels, by the air diffusers manufactured by Activated Sludge Ltd. Only part of the plant was repaired at Woodstock, so that the unit replacement costs are hardly comparable as between Woodstock and Timmins.

* Filtros plates in concrete troughs replaced by air diffusers and independent pipe connections.

† Minor changes in sludge lifts and air piping and replacement of several air diffusers.

It would appear from the summary that an operating cost can be realised which makes this system extremely attractive, especially to a Province which owns and distributes electric energy at cost.

The figures that are grouped in Table 2 give three years' experience at Woodstock, which tends to indicate that annual costs do not greatly vary. The cost of sludge disposal at Woodstock is greatly modified by the existence of adequate sludge storage tanks. Table II includes all charges in connection with the handling of three years' accumulation of sludge.

Table III has been compiled for the purpose of outlining the provincial situation with respect to existing plants. Where complete oxidation works are required, the trend is towards converting the works over to the activated sludge process. This can in the majority of cases be done more economically than by putting the existing systems into proper working order and providing the supervision essential for the proper maintenance of the old processes.

In concluding this paper, it is interesting to point out that, prior to 1913, more time, money and energy were actually spent in sewage disposal and sewage disposal plants than was being spent on water purification, and there was a definite holding-up of main drainage programmes, because these programmes would either increase the flow to already overloaded works, or because the sewage disposal works were not included with the application.

The situation is entirely changed at this time, and there has been a general speeding up of main drainage programmes, municipalities now being very well served by sewers in Ontario, and a very definite interest is being taken in water treatment, practically all the Great Lake water supplies being filtered or suitably treated; and the general situation with regard to the distribution of pure water is very gratifying.

TABLE II.

WOODSTOCK—ANNUAL COSTS.

Item	1921	1922	1923
Labour	$ .99	$ .78	$ .81
Power	2.11	2.50	3.20
Sludge Removal and Drying	—	.36	.09
Repairs, Alterations	—	*.86	†4.75
Yearly Capital Charges (Including Retirement)	10.20	10.20	10.20
TOTAL	13.30	14.70	19.05
Less Alterations	—	.86	4.75
	13.30	13.84	14.30

* Repairs to filtros plates.
† Replacement of filtros plates by Activated Sludge Ltd. air diffusers.

TABLE III.

ONTARIO MUNICIPAL SEWAGE DISPOSAL DATA.

Municipality.	Type of Sewage Works.	Date.	Population.	Tank Volume Imp.Gal.	Total $	Capital Cost $ per head	Effluent Discharged into.
Barrie ..	Septic tanks . ..	1909	7075	162,500	14,000	1.98	Lake Simcoe
Bowmanville	Imhoff tanks and sprinkling filters ..	1913	3574	37,500	19,152	5.35	Creek
Brampton	*a*Septic tank and activated sludge ..	1906 1918	4778	90,000 Aer.45,000 Sed.50,000	5,000 17,000	4.60	Etobicoke R.
Bridgeburg	Septic tank	1913	2450	90,000	5,000	2.04	Niagara R.
Burlington	Imhoff tanks and sprinkling filters ..	1915	2516	62,500	33,500	13.30	Lake Ontario
Carlton Place	Imhoff tanks . ..	1912	4254	140,000	14,000	3.30	Mississippi R.
Cochrane	*b*Activated sludge ..	1924	2868	Aer.100,000 Sed.	43,000	15.00	Sewage Lake
Collingwood	Septic tank	1905	6000	48,000	6,000	1.00	Nottawasago Bay
Crystal Beach	Activated sludge ..	1922	6000 Summer	Aer.40,000 Sed.12,000	12,000	2.00	Lake Erie
Dundas	Tanks and filters ..	1914	5070	210,000	100,000	19.70	Dundas Canal
Galt ..	Septic tank	1912	13,222	90,000	22,000	1.66	Grand River
Guelph .	*a*Tanks and filter beds Activated sludge ..	1909 1922	18,420	240,000 Aer.310,000 Sed.205,000	73,352 83,500	Trunks also 8.60	Speed River
Haileybury	Septic tank	1906	1883		4,512	2.40	Timiskaming L.
Hamilton	*c*Imhoff tanks, lime precipitation, sprinkling filters	1896 1897 1910 & 1914	120,234		193,000	1.60	Burlington Bayou Lake Ontario.
Kitchener	*d*Tanks, filter beds, sewage farm ..	1904 1915	23,571	480,000 280,000	137,000	5.81	Snider's Creek
Leaside	*e*Tanks and filter ..	1914	374	28,000	14,000	37.50	Don River
London	*f*Tanks and sprinkling filters	1916	61,369	32,000	50,000		Thames River
Napanee	Tanks and filters ..	1912	2986	58,000	35,000	11.70	Napanee River
New Liskeard	Septic tank	1910	2033	70,000	10,000	4.93	Wabi River
North Bay	*g*Septic tank	1914	11,768	125,000			Lake Nipissing
Oakville	Septic tank	1911	3566		12,190	3.42	Lake Ontario
Orillia ..	Tanks and farm ..	1908	7743		47,000	6.05	Lake Simcoe
Oshawa	Tanks and filters ..	1910	14,036	90,000	7,500	0.53	Lake Ontario
Preston	*d*Tanks and filter	1906 & 1908	5576	80,000	16,000	2.87	Speed River
Rainy River	Septic tank		1394		11,000	7.90	Rainy River
St. Thomas	*h*Septic tanks	1909	17,779	1,116,800	20,000	1.13	Kettle Creek

TABLE III.—*continued.*

ONTARIO MUNICIPAL SEWAGE DISPOSAL DATA.

Municipality.	Type of Sewage Works.	Date.	Population.	Tank Volume Imp. Gal.	Total $	Capital Cost $ per head	Effluent Discharged into.
Simcoe .	Imhoff tanks and filter beds	1914	4049		34.388	8.50	Lynn River
Stratford	Tanks and sprinkling filters	1923	18,244	Aer.120,000	60,000	4.73	Avon River
	Activated sludge ..			Sed.296,000	26,325		
Tillsonburg	Septic tank	1910	3086		2.500	0.81	Otter Creek
Timmins	Activated sludge ..	1921	7725	Aer.220,000 Sed. 50,000	58,750	7.60	Mattagami R.
Toronto	Sedimentation tanks.	1911	529,210		2,400,000	4.53	Lake Ontario
Trenton	Septic tanks.. ..	1910	5881	50,000	4,000	0.68	Trent River
Waterloo	Tanks and filters ..	1906	6096	115,000	33,000	5.41	Creek
Weston	Imhoff tanks and filters		3569		24,189,	6.78	Humber River
Whitby	Tanks and filters ..	1914	4174	210.000			La e Ontario
Wingham	Septic tank and filter	1910	2440	75,000			Maitland River
Woodstock	Tanks and filters ..	1902	10,196	100,000	7,000	7.22	Thames River
	Activated sludge ..	1921		Aer.450,000 Sed.130,000	66,500		

a Original tank converted to activated sludge. *b* Provided for double population. *c* Four plants. *d* Two plants. *e* Designed for 1,000 people. *f* East end works only. *g* Plant destroyed 1922. *h* Activated sludge plant under way.

DISCUSSION.

Mr. G. W. FULLER (New York), who read Mr. Dallyn's paper, in the absence of the author, said it appeared that the activated sludge process was a most acceptable plant to the Ontario provincial authorities, but he called attention to the fact that conditions in Ontario were quite unique, in that that branch of the Canadian Government was interested very much in hydro-electric power development. They transmitted electric current with the aid of facilities owned by the public, with the result that the cost of current was very low. Also, in places where the current from the Niagara Falls plant was not available, it was the practice to have municipal electrical undertakings. Therefore, the situation in Ontario in respect of the cost of current for the application of the activated sludge process was unusual. Again, the sludge could be digested to Mr. Dallyn's satisfaction either in lagoons or in the single-storey tanks which were to be found alongside the activated sludge plant. The combination was economical, and gave very satisfactory results from the point of view of quality of effluent. Mr. Dallyn and his board were to be congratulated upon having obtained these very satisfactory results.

REGULATIONS CONCERNING SANITATION OF DWELLINGS.

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The above question cannot be treated without touching to a certain extent upon the drains of the site. On this subject I can, however, confine myself to some minor points of contact between the interior and exterior drainage.

As regards drainage of dwellings and sites England must, with every reason, be regarded as the pioneer. Thus English regulations bearing upon such drainage have served as a model for other countries. It is only natural, however, that further experience will lead to changes in principles as well as in minor points. For instance, in a cold climate, such as that of Sweden, it is necessary to arrange all waste-pipes inside the house. If the pipes were placed on the outside of the walls, they would soon burst owing to frost. But, as will be shown below, it is not only such natural differences that distinguish the English and Swedish drainage regulations, there are also others about which opinions may differ.

It is not my purpose to enter into details or to present the question in its entirety, but only to set forth some more important views, especially as these have been voiced within the Swedish Association of Municipal Engineers (see its publications 1917, No. 17) and in the regulations of the largest city in Sweden, Stockholm.

As to the obligation to submit drawings to the authorities, and the duty of the latter to examine the same (and other purely administrative and formal matters) there seems to be little worthy of remark. It may be of interest, however, to know that in Swedish towns the owner of an estate can be forced to make a connection with the sewer as soon as the city has laid a conduit in the street. To administrative measures of some significance belongs also the appointment of plumbers, whose competence is tested by the authorities. In most of the larger towns nobody is allowed to execute this kind of work without licence, and the contractor is held responsible until the construction has been inspected and approved.

Afterwards the owner is responsible for the satisfactory condition of the drains.

The authorities dealing with these matters differ in different places, but as the Public Health Act authorises the Board of Health in towns to give permission in each special case for w.c.-installations, it has often, as for instance in Stockholm, been considered advisable to let the Board of Health decide on all drainage questions within the dwellings and on the sites. Where connection with the common sewer is concerned, this authority co-operates with the department within whose province this falls. The right to issue regulations, to impose penalties, etc., belongs to some government authority (the Governor-General's office in Stockholm, the Provincial Government office in other parts of the country) corresponding, in this respect, to the English Ministry of Health.

As to special points connected with the putting in of pipes—covered by the regulations in force—the following may be noticed:

As *material* for pipes and pipe-fittings indoors cast-iron is extensively used, more seldom lead or other metals. In special cases (as in conducting acidulous liquids) stoneware is used, but according to special regulations. Out of doors stoneware as well as concrete occurs to a certain extent. But numerous fractures in conduits of non-metallic material have caused it to be prohibited in Stockholm for conducting water to or through a lower situated iron-pipe, because a leak in the former would render the more expensive iron-duct objectless.

The English method of embedding stoneware pipe in concrete is employed comparatively rarely, but may be prescribed in special cases.

Regulations concerning types and dimensions, as well as quality, are worked out by the Swedish Association of Municipal Engineers, and are later adopted by the respective municipalities, each of which decides about them. The Swedish standards are such that also foreign pipes and fittings may enter into the system. Those interested in details are referred to the Transactions of the Association (1918, No. 9; 1923, No. 8) and to the regulations of the respective towns.

Sanitary appliances (lavatories, w.c.-pans, urinals, sinks, etc.) must be approved by the respective authorities before being installed. As a rule types known and used at home and abroad are employed. Only in regard to w.c.-pans does there exist a special type in Sweden, to which I shall refer below. At present there are two manufactories of sanitary appliances in Sweden.

In this connection it might be mentioned that enamelled cast-iron as a material for w.c.s is hardly to be found in Sweden.

As to the planning and inclination of the pipe-lines considerable liberty exists, perhaps even too considerable. Of course certain slopes are prescribed for non-vertical pipe-lines, but there is nothing to prevent a rising stem being conducted zig-zag, in other words to continue with a slight slope in the double flooring of an upper storey, then vertically through the same storey, then once more slightly sloping, and so on. It is evident that several slightly sloping conduits are thus obtained,

not only in the cellar and below the cellar-floor, but also in the upper double-floors. No leaks or other inconveniences have shown themselves due to this arrangement since the regulations were made.

For connections between cast-iron pipes and fittings lead is commonly used on sloping lines ; on certain conditions (careful water-test) cement is allowed. When pipes are carried through boiler-rooms, especially above the boilers, cement is deemed preferable. Rising ducts are usually jointed with red lead. For pipes of concrete or stoneware asphalt, clay or cement is used, depending on local conditions.

Considerable difference exists between English and Swedish pipe-lines regarding arrangements for inspection, those in Sweden consisting only of so-called cleansing-openings on the pipes.

Inspection-chambers of large type, somewhat, though not exactly, similar to those in England, are only found in large systems. In ordinary houses it suffices with the above-mentioned cleansing-openings, placed close to the points where the line changes its direction. In all cases a cleansing-opening must always be found near the foundation, where the duct from dwelling or site leads to the common sewer.

Interceptors between house-sewer and street-sewer do not occur. Consequently the so-called antisiphon-pipes are unnecessary, except where secondary water-traps are used (as for instance on bath-room stems). As a rule, however, there are no secondary water-traps, nor antisiphon-pipes.

One point of contention, not settled as yet, is the question of *gullies with collection-chamber* (w.c.-flushings are not allowed to enter such gullies). On the one hand it is held that the common sewer is protected from getting stopped, and water-courses are protected from a certain degree of contamination. On the other hand it is held that the collection of filth and the periodical removal of the same constitute an intolerable inconvenience from a hygienic point of view, moreover that if such a gully is clogged up with filth, every other imaginable advantage of it is illusory, and, finally, that the really harmful matter (fine slime) is not retained in the gullies, but is always carried on to sewer and water-course. For trapping sand, etc., during heavy rains gullies are considered suitable. Otherwise they are generally condemned.

As regards choking with rime frost it has been considered necessary in some parts of the country to prescribe four inches as the least diameter on that part of a rising pipe-line which is exposed to the cold, viz., in unheated attics and above the roof. Experience has proved that even this size may be insufficient in prolonged cold weather. The warm, moist air from below deposits rime in the colder part of the pipe, and this may continue until the whole pipe is choked with ice.

Among more important differences between English and Swedish installations the so-called *seat-ventilation of w.c.s* may be mentioned.

In England it is the rule that the w.c. should be ventilated directly to the open air. This is not the case in Sweden, where—especially in larger towns—it is found difficult to place the w.c.s by an outer wall.

They are generally situated in small closets and passages in the different flats. If bad odour escapes into such a w.c.-room, it will readily penetrate to the living rooms. One principle in the removal of all kinds of gases, steam, dust, etc., is that they should be removed *where they are generated,* without first being allowed to spread in the air. A satisfactory result may thereby be obtained with a mere fraction of the ventilation needed where the gases are allowed to spread. On that account it is prescribed in Stockholm (with more than 70,000 w.c.s) and several other towns, that ventilation from the w.c.-pan must be arranged. The pan is provided with a special opening, not found on the w.c.-pans abroad, which opening is connected with a ventilation-drum by means of a vent-pipe. The idea was originally proposed by a ventilation engineer. In some quarters, however, great objection has been taken to an arrangement "not to be found in other countries." To me it seems that in this respect Sweden is ahead of other countries.

Among modern demands in the province of drainage-systems may be mentioned the gasoline-separators in garages. If they really fill their intended purpose, to prevent gasoline from escaping into the sewer, seems somewhat doubtful. It is a fact, however, that such explosions are extremely rare.

It remains to touch upon the control over work of this kind.

In the better-regulated municipalities the control is very effective. No pipe-line may be covered in, either in the ground, or in a pipe-duct in the building, without being surveyed in detail by an inspector, whose duty it is to go over every new installation or alteration in an old one. When everything is ready, the final inspection is made by a higher officer, a physician or engineer. If differences have arisen between the contractor and the inspector, which have not been settled, they are now finally settled. Rarely does it happen that a higher authority (the Board of Health) is appealed to.

The present pipe-inspection has been in force in Stockholm, for instance, since 1908, with only few changes. In comparison to the time England has had such an institution, this is a short time, so short, indeed, that many installations remain from the time when there were no regulations whatever.

In a certain sense the Swedish pipe-inspection has hitherto worked during a transition-period, and this must not be forgotten in judging the results. It is my belief, however, that these results may be described as rather good and promising for the future.

AMERICAN MODEL PLUMBING CODE.

By Wm. C. Groeninger,

Past President American Society of Sanitary Engineering.

Sanitary plumbing is the art of installing in buildings the pipes, fixtures and other apparatus used for introducing the water-supply and removing liquid and water-carried wastes. It represents an art upon which all civilisation depends, and must be installed in accordance with scientific principles and natural law.

There is nothing in a building that adds more to the comfort and convenience of the occupant than does a simple, efficient and economical system of plumbing. Did you ever attempt to realise what would happen to your city if all buildings were deprived of a plumbing system? The thought of deprivation is terrible when you begin to think about the insanitary condition that would follow and the nuisances that would result, also the increased number of breeding places for flies, mosquitoes, rats and other well-known carriers of communicable, contagious and infectious diseases.

The modern home, factory, school, theatre, office building, hospital, hotel and public institution of to-day, would not and cannot be successfully operated without a system of plumbing and drainage. The removal of infectious material from buildings is of value to public health. The mental and physical health of the occupants of a home is dependent in a great measure upon the sanitary conveniences. They are essential to the cleanliness of both the person and apparel. The cleanliness of the body is simplified by the bath tub and shower bath. The cleanliness of the apparel is simplified by the laundry trays. The cleanliness of the hands, by which many diseases are transmitted to the mouth, is simplified by the lavatory. The sanitary condition of the kitchen and the cleanliness of cooking utensils and food is in a great measure dependent upon the kitchen sink. The sanitary drinking fountain has eliminated the danger inherent in the use of the common drinking cup, and the sanitary water closet is the safest method of removing human excrement and

urine, which are the greatest hazards to man. The modern convenience has eliminated thousands of foul germ-producing privy vaults, the chief breeding place of that disease-carrying pest and menace, the common house fly. The elimination of the privy vault has also removed one of the homes of the rat, another pest which is a very expensive boarder and a known disease carrier.

The intelligent real estate dealer is aware that a system of plumbing increases the value of the building far beyond the actual cost of the plumbing system. The hotel manager is able to charge from fifty cents to a dollar a day more for a room with sanitary conveniences. Running water in hotels is now considered a necessary adjunct by the travelling public. The plumbing system in a hotel not only adds to the comfort, convenience and health of the patrons, but is a source of revenue, which brings large returns to the owner.

The housewife of this country owes a debt of gratitude to the plumbing business because of the progress and measures adopted to lighten the labour of house work. Cooking, washing and the removal of body and domestic wastes, formerly drudgery, are now simplified by sanitary conveniences. Formerly water had to be pumped or lifted and carried from the well, cistern or spring for drinking, cooking, laundry, bathing and other household purposes, and the wastes had to be carried and emptied. The water was often of questionable quality. The method and place of waste disposal in nine out of ten cases resulted in a nuisance. The backyard privy, located at the greatest distance from the house to remove the possible odours in summer, added to the discomfort and inconvenience and the possibilities of added difficulties and irregularities in bad weather.

Go back thirty years, or even twenty years, and compare women's work then and to-day, and it will be found that most of the drudgery existing has been eliminated by the plumbing system. Hot and cold water for drinking, bathing and domestic purposes is conveniently arranged for use in the laundry, kitchen, bath and bedrooms. Domestic and body wastes are swiftly and safely removed from the immediate premises by the drainage system. Labour has been reduced, comfort and conveniences added and personal cleanliness simplified, pure water supplied, foul odours, unhealthful conditions and the elements favourable to the origin and development of disease have been removed.

Low first cost in plumbing installation is mistaken economy. A second-class plumbing and drainage system in cost will prove itself a second-class system in service. A year or so in service will reveal the inefficiency of the fixture, device or construction. Discomfort, inconvenience, cost of repairs, foul odours, insanitary and unhealthful conditions are the resulting penalties, which the occupant must pay.

Sanitary plumbing is of more real value than medicine. Plumbing provides means for keeping the body, wearing apparel, the house and our streets and alleys clean. Cleanliness means healthfulness. A plumbing system stands for cleanliness, which also means that the

plumbing system prevents where medicine cures, and prevention is more desirable than the cure.

Investigation has shown that in the absence of sanitary regulations and whenever each person is permitted to install a plumbing system according to his own ideas, insanitary conditions are sure to prevail. Shall the standard of plumbing regulations be determined by the person who lives in the house, by the owner, the manager, real estate speculator, material manufacturer, or in conformity with the standard of living and decency?

A great many people still cling to the idea that plumbing codes are created and laws enacted for the sole benefit of plumbers and that the public is made their legalised prey. This idea is kept in motion by real estate speculators, specialty and material manufacturers and others whose only interests are mercenary. No humanitarian, social, moral, financial or sanitary argument can be adduced against the enactment and the standardisation of plumbing codes by State and nation. This will not only eliminate commercially interested individuals and corporations, but any other organisation whose interests are purely selfish.

To protect the public from insanitary plumbing and the influence of harmful surroundings caused by reckless competition, the use of cheap and defective material and improper installation, sanitary regulations are provided, regulating the location, construction, installation and inspection of plumbing.

In America we have been thinking for years in terms of standardisation of plumbing practice. We have been looking longingly at the stars, thinking of universal, minimum, standard plumbing regulations, but have continued along in the lowlands. High ideals have been our goal, but the daily grind of the day's work has held short of realisation. At each meeting of a Sanitary Society some progress has been made; something has been achieved to meet the demands of modern practice, something but not enough. We know that universal, minimum, standard plumbing regulations mean standardisation and that standardisation means efficiency and economy in practice. We also realise that sacrificing efficiency for economy would be false economy.

Many agencies have been at work studying to bring about working standards, standards that are universally applicable to all classes and kinds of buildings in all cities and rural communities, standards that are feasible and consistent with that factor of safety so necessary when the comfort, convenience and the health of the people are concerned; standard regulations that will make it possible for any State or city to apply the same kind of regulations and to prevent the same kind of insanitary and unhealthful conditions. The great trouble is that there has been no unity of action, no central point of co-operation. The various organisations have gone along in their own way without that co-operation of effort which is so necessary for a common enterprise or movement. For thirty years I personally have been a close student of this subject; part of the time in an advisory capacity to the Ohio State Building Code

Commission and as a member of The American Society of Sanitary Engineering. For years I have studied to acquire knowledge for the benefit of my own State. My former position has brought me in direct contact with the necessity of having universal, minimum, standard plumbing regulations. Thirteen years ago we had in the State of Ohio thirty cities with thirty plumbing codes that were widely separate in their requirements. What was considered good practice in one city was considered bad in the other. The ordinance or regulation was only effective in the city limits. Complications, confusion, ill-advised specialties, inconsistencies and lack of impartial enforcement were some of the conditions. The passage of the Ohio State Plumbing Code gradually eliminated the conditions. One by one the cities fell into line. A movement of this kind cannot be revolutionary but can only be accomplished by evolution. Local pride and prejudices, coupled with indifference, are two of the greatest difficulties that must be overcome.

It has been said on many occasions by men of ability that a national or federal code could and would not be practical for all localities. It is my opinion that the basic principles and suggested code contained in the report of the Sub-Committee on Plumbing of the Department of Commerce Building Code Committee are adaptable and enforceable as standards for States and cities. Obviously small and minor changes and additions may be necessary in various sections to suit the climatic and other local conditions, but in the main the principles underlying plumbing science and sanitation are the same everywhere and need be standardised.

The report of the Sub-Committee on Plumbing is the first recognition that the United States Government has given to the business of plumbing. Just think of a business as important as plumbing and drainage that has not been recognised in more than a century. Why was this ? Not because of the lack of knowledge on the subject by those in or at it so much as a lack of knowledge on the part of the consuming public. The lack of printed authoritative knowledge on the subject of plumbing and drainage and the lack of uniformity of practice and wide discrepancies found in plumbing codes are mostly responsible for the condition of the business.

American colleges and universities teach everything but plumbing. Some trade organisations teach plumbers to be merchants. They also teach plumbers to be better business men. They have arranged to supply the demand for plumbers with thoroughly trained men through the apprenticeship system, but the foundation of all of this must be built on a basis. What is that basis ? Our answer would be universal, minimum, standard plumbing regulations equally operative and enforced without fear or favour. A people's plumbing code dependable and defendable.

Dependable to prevent a like nuisance in the States of Louisiana, Ohio, Washington, Florida or California.

Dependable as a code that will ensure the health of the people and prevent insanitary and unhealthful conditions.

Dependable because it is scientifically practicable, ensuring the greatest protection of health at a minimum cost.

Dependable because it gives the same protection to those in the rural and urban districts as it does to those in the populated cities.

Defendable because it is a people's plumbing code written entirely in the interest of what is good for the people.

Defendable because it eliminates the inconsistencies, indifference, local pride and prejudices found in many existing codes.

Defendable because it recognises that good plumbing is a matter which concerns health and the Government has the right to protect the people's health.

While the work of the Sub-Committee on Plumbing is a real accomplishment the work has only begun. The work of the Department of Commerce and the Bureau of Standards should not stop. It should go on and on keeping abreast with the times. It is hoped that the engineering societies, organisations of plumbers and the public in general will insist that the United States Government continue this work.

TWO HOUSE DRAINAGE SYSTEMS—WITH THE ATLANTIC BETWEEN.

By John S. Hodgson,

Washington, D.C.

In contrasting what may be conveniently designated the English with the American system of house drainage the most prominent distinction is found in the almost universal use of the main-drain intercepting trap in the former and its general omission in the latter. Intimately connected with this is the English interposition of an "air-break" between the liquid house wastes and the branch drains, as distinguished from the unbroken connection prevailing in America.

The element of time—embracing the different periods in which the two countries were respectively confronted with the task of formulating principles and framing regulations in this field of engineering—was a potent factor in determining the divergent courses pursued. England, as the pioneer in the general adoption of the water-carriage system of sewerage, suffered not only from the results of an initial and excusable failure to recognise the necessity of good design and generous outlay for the more or less hidden construction involved, but also from widely prevalent misconceptions in regard to the composition and qualities of what was popularly known as "sewer gas." Under the tutelage of well-meaning doctrinaires, it became an article of faith that immunity from dreaded dangers could be obviated only by heroic measures. These finally resolved themselves into an absolute severance between the dwelling and the drains by means of an "air-break" at the points where waste-pipes emerged from the building. Although obvious practical considerations made this cut-off inapplicable to any but liquid wastes, enthusiasts were not lacking who advocated the extension of this method to water-closet discharges. At least one distinguished architect urged the use of a light casting on the lines of a rain-water cistern-head as an outdoor receiver for upper storey water-closet outflows, and the designers of some town sewers went so far as to recommend the insertion of a syphon trap on the street sewers just above their junction with manholes, with the idea of preventing the passage of "sewer-gas" from the main sewer into and along the branch. In the one case of actual con-

struction known to the writer (a combined system) trouble arose from stoppages in the 9-inch and 12-inch syphons.

A concrete exposition of these views was found in a report, dated January, 1876, on an outbreak of typhoid fever in Uppingham School—a pronouncement which may be credited with a large share of responsibility for the uncompromising tenor of the original model by-laws, issued by the Local Government Board in 1877. The writer, then and for some years later engaged in the design and construction of sewerage works for urban and rural sanitary districts in the north of England, endeavoured on behalf of his clients to secure modifications of that Procrustean code which would have abundantly met all local needs, but in every case without succcess. The tenets of the Uppingham report had gained a firm foothold, and not even the adverse conclusions of the 1912 Departmental Report on Intercepting Traps have been able to relegate them to the limbo of history.

America, taking up the problem at a later date, was fortunate in being able to use more reasoned teachings as a starting point. While the idea of main-drain interception gained considerable early support, its application took the form of an unventilated deep-seal syphon trap, usually visible below the basement or cellar ceiling. Favourably placed at the foot of the cast-iron soil-pipe extending vertically through the roof in one direction and leading horizontally to an outside drain in the other, this feature was known as "the running trap." But even this concession to the ancient sewer-gas bogey has gradually given way to the belief in a free circulation of air between the street sewer and the roof ventilating opening, regardless of the variable direction of the air current. A partial exception is found in the capital city of Washington (population 470,000), where the former compulsory adoption of the English main-drain intercepting system is evidenced by numerous 6-inch circular grids on front lawns and street sidewalks. Dating from July 1st, 1914, however, a special permit for the insertion of a "running trap" must be obtained by an owner desiring such use. But the winter climate of North America, even as far south as Washington, effectually bars the adoption of the "air-break" method of dealing with liquid wastes and, incidentally, disposes of an unsightly domestic feature.

Coming to the intrinsic merits of the two systems, the single down-pipe, receiving all wastes in turn, offers an obvious advantage in the utilisation of flushing power as compared with the numerous ineffective driblets of the other plan. The absence of intermediate channels and "air-break" gullies—the latter facilitating the admission of much larger objects than can pass through the guarded wastes of indoor fittings—eliminates these objects as a factor in the determination of drain sizes. In this way, the design becomes more of a simple hydraulic problem, resulting in smaller drains and higher velocities than, within the writer's experience, are customary in England. In particular, with due regard to the contraction of the water-closet outlet, not only may a 3-inch soil-pipe be safely and advantageously used, but a 6-inch

main drain is unnecessarily large for any but exceptional cases. In this connection, the writer is unable to see any necessity for the unæsthetic outside soil-pipe—a provision which may easily militate against its erection at the point, on plan, otherwise most convenient for the purpose in view. It may involve the further necessity of comparatively long lines of almost level branch drains, even on the upper storeys, within the house. Each such line, leading to the alternative point selected for the soil-pipe, entails the provision of special and separate treatment in the matter of anti-syphonage "venting," with consequent complication and expense.

The more general use, in America, of iron pipe within buildings has probably contributed to the adoption of smaller drain sizes, with advantages measured not merely by the reduction in cost. The frittering away of available flushing power, as the result of excessive diameters combined with "air-break" disconnections, is forcibly illustrated by the statement, in the Departmental Report of 1912, that the tested intercepting syphons were found to retain "from 42 to 79 per cent. of the solid matters of the sewage passing through at any given time." This condition is in striking conflict with the canon of "constant movement" laid down by Chadwick, Rawlinson and other early advocates of the water-carriage system—an admonition strangely forgotten by some, at least, of their successors.

The omission of the interceptor acquires added importance when sewerage works on the separate system are being installed, whether by the construction of new works or the conversion of older combined systems. In either case, the desirability of excluding rainfall from the sanitary sewers precludes a continuance of the ventilating street manhole cover, with a consequent demand for a liberal provision of substitutes, these being most easily found in continuous house drains, each ventilated through the roof. A small but sufficient number of street air-inlets free from the influx of rainfall, would then assist in supplying the requisite degree of circulation.

In a discussion of this subject it would be worse than idle to ignore the liberal American attitude in the matter of water supply to domestic sanitary fittings and to water-closets in particular. This applies not only to installations in which the intermediate flush cistern is retained, but even in larger measure to those drawing the supply, through sufficiently large pipes, directly from the house service. The flushing effect of four gallons, delivered into the basin in six or seven seconds, must be seen to be appreciated. The bugbear of direct connection between the water service and the basin does not appear to disturb the minds of American sanitary engineers. Then, too, apart from the superlative scouring effect of liberal volumes of water, effectively applied, there is an indirect gain in the greater depth of trap seal thus rendered permissible. In this connection it may be noted that Washington, a non-manufacturing city, has an average water consumption of about 115 imperial gallons per head per day.

An attempt to crystallise the ultimate effects of the two systems into a single paragraph may not be without profit. In American methods there is a confident reliance upon scientific design, supplemented by the prescribed use of high-class fittings and workmanship and by a willingness to incur the attendant expense. The English system, on the other hand, seems to be based upon the assumed impossibility of securing any of these essentials, with a consequent falling back upon crude stipulations having the inherent and dangerous defect of instilling a false sense of security

DISCUSSION.

Mr. C. G. Klaarhamer (Holland), dealing with the question of district heating, said the difficulty in heating several houses from one boiler plant was that they could not sell heat to each house or each flat unless they could do it through a meter. On the other hand, if they included the delivery of heat in the rent of a house, the tenants were liable to take undue advantage of it, and use as much as they could, either on purpose or by carelessness. He referred to an installation in a block of houses containing forty-eight flats. There was one large radiator in the living room, and the tenants could keep the radiator open all day and night. In this case the cost of the delivery of heat was included in the rent. The temperature of the water in the radiators was regulated in the boiler house. But in Holland they have also another system, which was several years old, but which was not put into practice until about two years ago. By this system they could heat as many houses as they liked. One installation for fifty houses had been completed, and they are now carrying out an installation for 475 country houses, all heated through one boiler house. Plans are also ready for heating 2000 labourers' houses from one boiler house. Heating was carried out by hot water, and the heat was delivered to the houses through a meter. In winter time, during the hours when heat was not required, there was no water in the radiators or in the pipes, so that there was no danger of freezing. Once the practicability of the system was proved, they expected building costs to fall, whilst another advantage of the system was that the smoke nuisance was solved. There would be better living conditions, and decidedly less expensive heating. They had been forced to find a system in Holland by which fuel could be saved, because of its high cost.

Mr. J. W. Lockwood (Metropolitan Board of Works, Melbourne, Australia) said that the body he represented was created by Act of Parliament for the purpose of dealing with the water supply and sewerage of Melbourne. Up to the present, they had connected 180,000 houses, having a population of about 800,000 people. Intercepting (boundary) traps were insisted upon. In Melbourne there was a regulation which insisted upon closets being on the outside wall of a building, and they must be lighted and ventilated direct from the open air. He would like to know whether, in England and other countries, closets were allowed inside buildings other than in compartments having external walls. In some of the large hotels and other places, where there were suites of rooms, the architects said that they could not advantageously plan the buildings to provide direct lighting and ventilation from an external wall. In some cases they wanted a w.c. opening directly off a bedroom. He believed that was done in America, and asked whether there was any objection to that practice. In Melbourne, as in other countries, they wished to minimise the cost of house connection work. On the application of any householder, architect, or agent, the board prepared a plan for the house connections, or the architects would submit their plan.

If the board prepared the plan, forty feet to an inch, they charged 5s. per closet for it—showing the position of all the fittings and the line of drainage. In places where there was only one closet, that fee did not pay, because it cost more to prepare the plan that was received for it. Supervision was another important matter, and the board supervised the whole of the work. They employed drain testers—men used to jointing pipes, etc., and they supervised the plumbing also, free of cost to the owner, thus relieving the architects and owners of practically all the supervision. Then, when the work was completed, if satisfactory, a certificate was issued. They had a very complete set of by-laws, which was regarded almost as a specification, so much so that architects, in preparing specifications, stated that the works should be carried out in accordance with the regulations of the board, and very often they added that the cost would not be paid until a certificate issued by the board had been produced. Dealing with inspection chambers on a system, Mr. Lockwood said they did not insist upon those unless there were three or more houses combined in the system, and he did not know that they were of very much use, except for testing purposes. As to licensing plumbers, they did not allow any man unless he possessed the licence of the board, to carry out any sewerage work whatever. The board had nothing to do with the house construction work, and whether the plumbers were licensed or not did not matter, but very often the men who carried out the house work held the board's licence. Whenever there were sufficient candidates, examinations were held, and the board issued first and second class licences ; the men who were doing the sewerage work were getting a higher rate of pay than the ordinary plumbers, and were more highly skilled. With regard to supervision, Mr. Lockwood asked whether it was the practice in other countries to have plumbing inspectors to supervise the plumbing work and the house drainage work. In Melbourne the board insisted upon a gully trap in every instance. The houses in Australia were mostly detached, and where there was not an internal closet, or slop hopper, there must be a receptacle into which the inhabitants could dispose of certain slops, etc.

Mr. H. Alfred Roechling (Westminster), urging the retention of the intercepting trap, said that one of the important things which an engineer did when designing his work was to adopt a factor of safety. Sanitary engineers ought to adopt a factor of safety in their work, and he looked to the intercepting trap in the main drain as such a factor of safety, which should not be discarded without sufficient reason. Our methods for investigating bacteriological problems were still somewhat crude, and, that being so, it was utter folly to say that the intercepting trap was unnecessary. We were bound to do everything we possibly could for the maintenance of health.

Mr. F. C. Temple (Jamshedpur), describing conditions in India, said that, in the first place, sewerage schemes were very rare there. The

method of nightsoil removal was generally by hand. One very ancient form of privy was that known as the pot privy, which consisted of a large earthenware pot, holding about twenty-five to thirty gallons of water, sunk in the ground. The remarkable thing about it was that it worked reasonably well. The habit of the Indian was to cleanse himself with water, which he took with him in a small pot, and after cleansing himself he poured the remaining water into the pot privy. The effluent, such as it was, soaked into the soil. When there was a piped water supply to furnish drinking water it was remarkable how well it could work. When there was not a piped water supply it still worked far better than one would imagine, though nearly every well in the town was probably brackish, for the reason that it was absorbing the salts of some thousand years of urine and other excreta.

An improvement on that was Griffin's Aqua privy. This was a large pot with a special seat, through which flies could not reach the nightsoil and cause maggots to breed, and it had a small overflow for excess liquid. It was impervious, and just so much water as was poured in at the top came out at the other end. The effluent that came out was remarkably foul. It was an instance of a very small dilution purifying sewage to a certain extent. It worked reasonably well if the effluent could be put into the land at once. As an illustration of how well it worked, he said there were 200 at present in the town with which he was concerned. They had been working for four years, and up to the present day only nineteen of them had yet needed to be cleaned out. They would sludge up very badly if overloaded, but would carry about six or seven people regularly. One "sweeper," as the cleaner was called, could look after forty of these, whereas one sweeper could only look after twelve of the hand removal type. He (Mr. Temple) had set out to see what he could do in the way of connecting small workmen's quarters to sewers. The rent of those quarters was not to exceed 6s. per month, so that, obviously, it was not possible to put in any kind of ordinary flushing system.

Therefore, he had devised a privy which consisted of nothing but a seat, that is two foot rests, over a trough, which had a slope of one in thirty. Curiously enough, in India they were able to persuade people to use privies without roofs. Everybody who had a privy in his little courtyard wanted a bathing platform as well. Therefore, he had connected the platform to the head of the trough. The bottom of the trough connected directly to the sewer without any intercepting trap of any kind, and there was no soil stack of any kind. The privies were mostly in pairs. There was a covered manhole outside the courtyard, to which the sweeper had access, and there was a short branch into the main sewer running down the street. The merit of the thing was that it worked, and people asked for it to be put in. There were certain difficulties that arose at first. The people would only pour water out of their "lota" (a little brass pot) into the trough, but would not pour in water from anything else. That was one of the reasons for connecting the bathing platform to the trough. It would break a man's caste if he

poured water down the privy except from his lota. He could pour it down the bathing platform from any vessel without losing caste. The system described had the advantage over the hand removal system that the nightsoil was partly removed by the water used from the lota; in the hand removal system, the nightsoil was only removed once a day. In his new system, Mr. Temple said that he sent a sweeper every day to pour water down, but if the tenant objected to waiting for the sweeper he could draw water himself and wash the nightsoil away immediately. The people were mostly entirely uneducated, and were very liable to throw other things into the trough, at the risk of blocking the sewer. It was hopeless to put gratings, because the nightsoil would stick to the bars, so he had put four-inch connections from the end of the trough to the sewer. In the little manhole or inspection pit just outside the man's garden they throttled the soffit of the pipe down to three inches, making the invert continuous. As they had a pretty good fall, they had been able to carry away down the sewers anything to pass a three-inch outlet. The main sewers were at least six inches in diameter, and the branches were four inches as a rule. He believed these privies broke nearly all possible plumbing regulations, and yet they were a means of putting in some connection from the houses to the sewers at a cost which was possible, and they had the merit that they worked.

Mr. Lorenzo Borring (Copenhagen) said that the drainage of buildings in Denmark was based on the English principles, just as was the case, he supposed, in all other countries, and, of course, it had worked very satisfactorily. But at the present time building is expensive, and they had been trying to simplify things in order to reduce costs, and also to reduce many of the nuisances which had been found in certain parts of the drainage system. They wished also to simplify the regulations concerning piping and drainage of houses in the whole of Denmark. Hitherto practically each town had its own regulations, but a committee had been set up, principally by the Civil Engineering Club of Copenhagen, which had worked out regulations, and which was to make similar regulations to apply all over the country. That was very much desired by consulting and public engineers, as well as by plumbers. The Town Engineer of Copenhagen, Mr. A. C. Karsten, who was chairman of this committee, had for many years done much to reduce the cost without reducing the efficiency of the drainage. They had been able to reduce the cost by 45 to 50 per cent., partly by eliminating the ventilation pipes of the w.c.s, and by omitting all unnecessary traps. They had always laid stress upon the necessity for having traps as good as possible to sinks, closets and all outlets, and had carried out a lot of research in order to find the best possible form of trap. The original trap was either an S form or a P form, but many others, especially the pouch form, had been tried. They had made many traps of glass and had fitted them up, in order to see the manner in which the water flowed through. With glass traps, and by using coloured water, they had a splendid

opportunity of seeing how they worked, and it was remarkable how differently the water made its way through different traps. As to ventilation pipes, they had been omitted, except in cases where there were two or more w.c.s on one side of the line of a vertical pipe, and they had also omitted all the traps underground, so that there was only one trap for each basin. The reason they were able to do that was that the vertical drain pipes went right up through the top of the roof, where possible. They had found out, by biological research, that the air in these vertical pipes, where there were no interceptors, was in a far better condition than when a trap was used, because when they were closed off by traps there arose fermentation and other biological processes which made the air worse. Where there was no trap, the foul air from the sewers and streets passed up the pipes, but the pipes also brought up a lot of fresh air, and, by oxidation, the bad effects were minimised. The piping was nearly always cast iron ; they had a lot of different forms of fittings, and the system worked very well. They used very little lead, except in special cases, where they wanted the pipes to be concealed. In Denmark, and especially in Copenhagen, the buildings were generally in the form of flats, five storeys high, with a main staircase, there being one flat on each side of it, and, as far as possible, they tried to fix the w.c.'s to the outer walls. In the case of new buildings, the authorities always asked that there should be direct fresh air into the room. At present, however, in order to reduce costs—which was of vital importance—they were building flats with only two or three rooms and a kitchen. In many of those buildings they had the w.c.s above each other in the middle of the building, but they always had at least indirect lighting, and a ventilation tube through the ceiling. So long as there was a good 10 cm., 4-inch by 4-inch, square pipe direct through the ceiling, and a narrow opening underneath the door, so that air could get in, the air must pass through, and it worked very well. The cost of building was reduced very much. As to piping, formerly they had always used iron pipes to carry wastes down from the houses, with a suitable gradient underground out to the sewers. To reduce the cost of piping, however, they are now making those pipes of glazed clay, which seemed to be quite sufficient. At the bottom of each vertical pipe was a little opening, so that they could always clean the pipe. Altogether, they had wasted a tremendous lot of money in the past in connection with the drainage of buildings, especially by installing the ventilation pipes which are now eliminated. The main thing to remember, of course, was that the piping must be good.

Mr. Louis Cantor (Jerusalem) referred to the difficulties in Palestine with regard to sanitation, because the laws of the inhabitants defied every principle of sanitation and hygiene. He also pointed to the splendid efforts which the British administration had made to improve the conditions there.

Mr. A. P. I. Cotterell (Past President) considered it was one of the advantages of this International Conference that we had such papers as those presented that morning. British engineers were obtaining a lead from their American friends. He was very interested to know that they stressed the omission of the intercepting trap, and he hoped that it might have its effect upon British practice. As a matter of fact, the omission of the intercepting trap, as well as some of the other alterations mentioned that morning, was absolutely dependent upon a good sewerage system. He supposed the reason why we in England had been so backward in regard to some of the improvements which our American friends had gone in for was that we had had to couple up our house drainage with somewhat obsolete, and worse than obsolete, systems of sewers, which were in such a bad condition that we were afraid of how they might affect our house drains. In America, he understood, many of the sewerage systems were modern, and were not like so many elongated cesspools, as we too often found them to be in England. The same remark applied to the practice of putting the w.c. inside the house when it was not convenient to place it outside. He must say, from his experience of American hotels, where one constantly came across such cases, that there was no harm whatever in this method. In fact, there might be a positive advantage. In England we insisted that the w.c. should be against the outside wall, and that there should be a window or other opening of a certain size, with certain further methods of ventilation. He had found the effect to be just the very opposite to that which the regulations intended to promote. The window was left open, and whenever the w.c. was used the smell was blown into the house if the wind were in that direction; therefore, we brought about the very state of affairs which it was the intention to avoid. If, on the other hand, the w.c. were placed internally, and with a suitable shaft, as was done at Copenhagen, and an opening under the door, so as to produce a regular draught, the trouble which we in England fell into would be avoided. Those were just two aspects of the points under discussion that had impressed him particularly. These discussions were helping us in England to realise that it was time to revise our antiquated methods. He was concerned at the moment with the design of the sewerage arrangements for a model village in Kent, and he was omitting the intercepting trap completely. He did it on the recommendation contained in the report to the Local Government Board in 1912, which very few seemed bold enough to follow. Much had altered since our by-laws were first evolved. Plumbing had improved immensely. The by-laws were framed for standards of workmanship and material that are scarcely comparable with present-day systems. America had undoubtedly led us in plumbing, and as we had also improved, we might very safely follow America's lead in regard to some of the other alterations advocated.

Mr. H. C. H. Shenton (the Chairman) said he was very glad to hear what Mr. Cotterell had said with regard to intercepting traps, and

considered that he was perfectly safe in omitting them. The way in which we in this country followed by-laws which certainly did not apply to present conditions was a matter for concern because it led to an enormous waste of money. The report on plumbing work which had been prepared for the United States Department of Commerce was of very great importance, and we in this country were indebted to Professor Whipple for bringing it prominently before us. The house drainage question had never before received anything like the same scientific attention as had been given to it by the American Committee of whom Professor Whipple was chairman. The great difficulty was to get people in this country to study that report. It was not to be doubted that most engineers regarded house drainage as something beneath their notice which they preferred to leave to the plumber; most architects did the same. It must be admitted, however, that this did not necessarily mean that the work done was of an unsatisfactory character. Certain contracting firms who carried out drainage and plumbing work were experts; the quality of their work and the general design was often excellent, but this could not be said of every contracting firm undertaking plumbing work. It was very improbable that plumbing firms would be likely to worry themselves to alter their practice in consequence of the findings of reports made by Government Departments; contractors had no time or inclination to agitate for changes in practice, even though these changes were the result of scientific experiment, and if made would lead to great saving of expense. Their work as commercial men was different from that of the professional engineer, and furthermore, if they, as contractors, wanted to make the changes suggested by Professor Whipple, they could not do so because local by-laws and regulations would prevent them. He (the Chairman) was quite sure that engineers, and particularly the advisors of the Ministry of Health and Local Authorities, were those who should endeavour to have certain changes made; he was quite sure that it was a safer and better thing to take the waste from a sink, lavatory or bath into a soil pipe, than to allow it to discharge through pipes which were often ventilated in dangerous places, and which discharged into a gully which was often a source of smell, trouble and nuisance; naturally there would be very great danger in adopting this practice if the work were not properly carried out, but he doubted whether the worst condition could be so bad as that actually existing at the present time in the majority of houses. It was perfectly false to think that because certain by-laws and regulations were made and followed, that the work was necessarily safe. It was not generally grasped how very imperfect the average house drainage system was; the whole country was full of work which would not stand criticism. As an example, they might take any large system of waste pipes from sinks, baths, lavatory basins and so forth; these pipes would become more foul than any well-laid drain would become. It was supposed to be safe to make them discharge into a gully in the open air. Every

flush that came down discharged a large quantity of air which was much more foul and much more dangerous than the air in the drain. He would consider the case of a hospital for infectious diseases; there was continual discharge through baths and sinks of disease germs. Was it safe to leave pipes, which took such wastes, discharging and splashing in the open?—or to have a gully in the open air becoming clogged with such matters as resulted from the washing of patients. The same thing applied in a smaller degree to the waste pipe of every private house. It was folly to imagine that the dirty water discharged from sinks, baths and lavatory basins was less harmful than ordinary sewage; on the contrary, in his experience it was frequently very much worse. He hoped that the Ministry of Health particularly would take notice of the report prepared in America and of Professor Whipple's paper. House drainage was a matter which required the attention of the engineer quite as much as the larger work of sewerage and sewage disposal, and it was even more important seeing the closeness of contact with every member of the community.

The CHAIRMAN (Mr. H. C. H. SHENTON) in proposing a vote of thanks to the authors, took the opportunity of expressing also his personal appreciation of the support given by American engineers. The conference had been held largely owing to the support received from America, and we, in this country, owed a very great debt of gratitude to the delegates from across the Atlantic.

The vote of thanks was accorded, and the Conference adjourned.

MODERN METHODS OF REFUSE COLLECTION.

By J. A. Priestley,

Cleansing Superintendent, Sheffield.

In preparing this paper I find myself handicapped by its title, which was suggested to me and accepted before I had given much consideration to how I should treat the subject, and I now find myself facing the fact that there is nothing essentially modern in the collection of refuse, which in itself is a practice of hoary antiquity and has been in operation wherever considerable communities were in existence, since the very earliest ages. It is true that there have been elaborations and modifications in methods or systems, but when these are reduced to their primary essentials, they consist of two agencies only—some form of labour to collect the refuse, and some type of vehicle to transport it. In one direction alone has any change occurred in these primary agencies, and that is in the adoption of water carriage as the transporting agency for personal refuse, but this is outside the scope of my paper which is not intended to deal with sewage problems. The difficulty of writing any paper of general interest within the limits of my title has led me to adopt the time-honoured clerical practice of using a text as a point from which to wander, and my subject therefore may more properly be described as a consideration of the circumstances and conditions which affect the collection of refuse in modern times, and their influence upon the methods in vogue.

In this country there have been a few instances of the almost instantaneous growth of large communities from small villages, but it is one of the misfortunes of a cleansing officer that he can seldom develop his conditions and his methods uniformly, and has generally to adapt his system to existing conditions which are the reverse of uniform, and necessitate not one uniform system, but a number of methods applicable to the varying conditions, and the result is that not only do no two towns present entirely comparable conditions, but no town can concentrate upon absolute uniformity. There are many factors which affect not only the quantity but the character of the refuse produced in a district,

and the responsible officer has to take all such factors into account in his organisation, and no methods which do not possess sufficient flexibility to meet the varying conditions can be successfully operated. The first factor is, of course, the refuse itself, which, whilst of remarkably average uniformity in this country, yet varies very decidedly in some districts. The refuse of a district whose population is principally engaged in the mining industry in some cases varies in quantity to the extent of 300 per cent. above the average, whilst both quality and quantity vary materially according to local industries. Where the local industry employs both men and women, many households are deserted during working hours, and this causes a production of bulky but light refuse, whilst cheap coal districts again produce much heavier refuse. Climatic conditions have their influence, and Devon or Cornwall towns are not comparable with those of Cumberland, whilst seasonal variations occur in all districts, that is, at least, in those years when there is any appreciable distinction between our summer and winter. The influence exerted by the composition of refuse is more considerable than may at first sight appear, as a variation of 100 per cent. in the weight per cubic yard of the refuse is bound to affect the collecting system, and this variation is by no means uncommon as between winter and summer, in the same district. Trade and shop refuse again is an influencing factor, and business districts require different treatment from purely residential areas.

Another set of factors influencing the subject are those arising from the arrangement of the district. Town planning is comparatively in its infancy, and the importance of considering the cleansing department's requirements has not yet dawned upon many officials engaged in this work, with the result that some town-planned areas are standing examples of inaccessibility as applied to refuse receptacles. Lancashire towns are conspicuous for the facilities provided for the removal of house refuse, as the system of secondary streets makes it possible to clear away the refuse from two adjacent streets without entering upon the house premises at all, and the advantages of this arrangement, over that in which the workmen have to carry the refuse from each house down long passages to the front street, is obvious. Blocks of flats or tenement houses are awkward propositions for refuse, collection and involve much additional time and labour, whilst kerb collections on the contrary facilitate the work materially, although there is a growing antipathy on the part of the public to be called upon to act as their own scavengers to the extent of putting out and returning the refuse receptacle, and there is much to be said in favour of the paid dustman being required to complete this duty.

A third set of factors are comprised in the types of receptacles in use, which in their turn are dependent upon how far sanitation has progressed in the district concerned. Where cesspools, privy middens, or pails, are still in existence, they require special treatment, but as these relics of barbarism have no place in modern ideals and are fortunately a diminishing quantity, they may be dismissed with this brief notice. The two

types of receptacles in general use are the fixed and the movable, the former usually known as ashpits, and the latter generally taking the form of galvanised bins, although wooden tubs are not infrequently used, and in some few cases any kind of bin, tub, box, bucket or other similar receptacle is brought into service. There are very few towns which have standardised the dustbin although such a course is of great assistance to collection work, and particularly so if the size is restricted to the necessary capacity to contain the average production of refuse between the intervals of collection. The usual fault of dustbins is that they are too large for their purpose, and unwieldy in handling, strength of construction being also sacrificed to capacity. In the North of England a receptacle known as Dr. Quine's Ashbin has found considerable favour, this being a galvanised bin or box with lift-up cover attached, the whole being fixed on a swivelling panel, which enables the receptacle to be tipped up into a basket, or skep, and the rubbish carried to the collecting vehicle. Where these receptacles are fixed in the back wall of the yard abutting on a secondary street, the collector and vehicle, passing down the street, can rapidly clear the refuse from a long double row of houses with little effort or trouble, the workmen in this case having no need to enter the premises at all.

The last set of conditions affecting collection are the intervals at which such work is carried out, the points of delivery, and the character of disposal system in operation. The usual period of collection for dustbins is weekly although a number of authorities give a twice weekly collection, whilst in others a daily collection is made, and in some parts of London a twice daily service is given. With fixed receptacles the intervals are usually longer, and any period up to three weeks may be found in operation. The most suitable intervals are usually determined by local circumstances, but weekly collections may be accepted as generally satisfactory in this country, as domestic refuse here contains a much smaller percentage of putrescible matter than is the case in hotter climates, and the ashes from the domestic fire certainly act to a considerable extent as a deodorant. More frequent collection, except where business considerations demand it, involves a heavy charge for the duplicated mileage covered, and is not, in my opinion, justified by any sanitary advantage obtained. Points of delivery and methods of disposal affect of course the size and construction of the vehicles employed, the system of haulage adopted, and the number of journeys possible, as short hauls are not generally favourable to mechanical transport, and heavy wagons which are quite suitable for good roads cannot be used for tipping on soft ground, whilst the nature of the available dump regulates the angle of inclination which can be employed in the tipping gear.

From a consideration of all these factors only can the most suitable method of collection be determined, and modifications of any general system are necessary to meet individual cases, but the most common method adopted where portable receptacles are in use is that of emptying

the bin direct into the collecting vehicle, the workman carrying the full bin to the wagon, and returning it when empty to the premises concerned. An alternative method is for the workman to carry skeps into which the bin is emptied on site, and this skep is carried to and emptied into the collecting vehicle. This method effects a saving in time, as only one journey from and to the waiting vehicle is necessary, instead of two where the bin has to be carried to and fro, but the refuse is twice emptied, and in windy weather more dust is apt to be blown about in the process. As, however, the skep is placed on the floor and the refuse is emptied from the bin at a low level this is not a serious drawback, and the system has the additional advantage, that bins are not damaged by bumping on the edge of the wagon. The skep system is now used in some cases for emptying dry ashpits, although these are more frequently emptied on to the street, and shovel-loaded into the wagon, a cheaper but decidedly more objectionable method of procedure. The question of dust prevention is one of the most difficult problems in connection with refuse collection, and many devices have been suggested and tried for its elimination, but with no great measure of success. Collecting vehicles are of course all covered in any well-ordered district, but the covering is only complete when the vehicle is loaded, and it is in the process of loading that most of the dust arises. Wind shields have been tried, but are usually cumbersome and inefficient, and sliding covers, which provide an opening for one receptacle only to be emptied at once, are hindrances to obtaining anything like a full load. A vehicle shaped like a pantechnicon into which the bins are taken and emptied, is in use in a few places, but these have to be unloaded by shovelling, and are unwieldy and expensive in operation. Dust prevention could be attained by substituting empty bins for the full ones at each house, and dealing with the full bins at the depot, and this would also permit of the thorough cleansing of each bin after emptying, but the cost would be enormous, and cleansing departments have to be operated in this country with sometimes more than due regard to cost. Efficient cleansing is usually worked on the district system, in which every vehicle has a given area allotted to it and the collection is continuous, fluctuations due to season or weather being covered by relief vehicles, which maintain the standard of frequency adopted. Records of the work done are essential, and usually each round has a printed list of the bins allotted to it, and the dustman marks off those emptied as he proceeds, and from these cards a continuous record of the cleansing of each receptacle is kept at headquarters, and any delinquencies can be checked by the inspector's surprise visits. The weighing of all refuse collected is also an important essential in cleansing administration, and affords a valuable check on the work done. In many districts a given number of loaders are allotted to each vehicle, and work with that one alone, but other authorities have relay vehicles which take up the work as the full wagon goes to tip. The economic value of this arrangement depends upon the number of loads done daily, the ratio between loading time and travelling time, and the maintenance

of a strict time-table, and in many districts it could not be advantageously worked. Collection by night is very seldom resorted to in the matter of dustbins, and its disadvantages are too obvious to require enumeration, but completion of the work of collection at an early hour is essential in some districts, and this involves arrangements of a special character to utilise the transport to its full extent, and this is especially the case where the same time limit is observed both as regards business and residential areas. Whilst in large towns the practice is necessary in the former case, it is somewhat of a superfluous refinement in regard to the latter, unless in the case of holiday resorts where special conditions prevail, and the extra cost involved is recouped from the visitors.

From the transport agency of collection, choice is limited to two classes, of which horse haulage is at present the most extensively used. For short hauls it is usually the cheapest, and is indispensable in some cases for otherwise inaccessible areas, where unmade roads, dangerous gradients, or narrow streets, make motor traffic impossible, and it is popular as the most portable type of tractor available, although there are some cases in which pride of horseflesh probably outweighs all other considerations. Two-wheeled carts are now much less in common use, and the four-wheeled wagon is more generally employed, but horse-drawn collecting vehicles have changed little in design for a generation. Where motor haulage is used, there is more choice and variety, and steam, petrol and electricity all have their strong adherents, although the former has the most limited vogue owing to the usual size of vehicle employed. Consensus of opinion at one time favoured the 2 to 2½ ton vehicle, but recent experience in some of our large cities now seems to indicate that five to six ton wagons are the most economical, where conditions for manœuvring permit of their use. Electric vehicles possess many features which render them particularly suitable for refuse collection, and some cities have concentrated on this type of wagon for the work, whilst one-ton petrol motors are successfully used in many smaller towns, and possess the merit of low initial cost and great flexibility. In transport work local conditions and circumstances are essential factors in determining the most suitable system to adopt, and no standard can be laid down for universal acceptance. The desire to eliminate the use of costly motor vehicles for the slow process of house-to-house collection, but to retain its advantages for travelling, has led to more or less successful attempts to combine horse collection and motor haulage, and two methods of accomplishing this are in actual operation. In one system the horse-drawn vehicle is raised bodily on to the truck of a motor wagon, in substitution for an empty vehicle, and the motor proceeds with its load to the depot, whilst the empty vehicle in its turn is loaded up and the process repeated, whilst in the other system a motor tractor collects a number of horse-drawn wagons, and leaves similar empty ones for loading. In the latter system one tractor may serve a number of collecting areas on the same journey, but the manœuvring of a number of loaded trailers into proper position at the depot involves some skill, and con-

siderable time. The selection of a suitable wagon body is important, and this requires to be of considerable capacity on account of the light character of house refuse, which has an average bulk of about $2\frac{1}{2}$ to 3 cubic yards per ton. End-tipping bodies are most generally employed, and the best tipping angle is usually obtained by the run-back device. Some excellent mechanical tipping devices are available, by means of which the whole load can be tipped in less than one minute. The use of loose bodies has not found much favour in this country, as it involves special arrangements at the depot for dealing with unloading, and except under special circumstances of disposal they offer no compensating advantage. Whatever the types of motor or body employed they usually have the disadvantage of a high loading line, which necessitates the use of loading ladders. When the refuse has to be carried long distances, this may not cause serious delay, but it is at all times an inconvenient and undesirable addition to the work of collection, and increases the risk of damage to both dustman and dustbin, and adds to the dust produced. There are a number of vehicles in use in which a low loading line has been secured, but usually at the expense of some other important detail, either capacity, size of wheels, or tipping facilities being sacrificed to this end. Notwithstanding the many improvements in design of refuse-collecting vehicles in recent years, the ideal wagon has yet to be produced.

Whether sanitary engineering will ever devise a system of refuse collection which will be independent of the itinerant dustman and his wagon, or not, is a speculative problem, but in view of the marvellous developments in other directions I should hesitate to pronounce it improbable.

No paper on refuse collection would be complete without some reference to street refuse, but I have only time to make a brief reference to the modern appliances available for this work. The crossing-sweeper has become a figure of history only, and motor brooms and watering machines, vacuum gully-cleansers and combined street sweepers and collectors, have all been added to the equipment of the modern street cleansing department, whilst dustless road construction, and the development of motor road transport, have very materially reduced the character and quantity of street refuse to be dealt with. Finality has not by any means been reached, in either the collection or the treatment of town's refuse, but I think enough has been said to justify a claim that we have at least progressed some considerable distance along the path of improvement.

RÉSUMÉ OF AMERICAN PRACTICE IN THE DISPOSAL OF REFUSE.

By Samuel A. Greeley.

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1. GENERAL.

American practice in the disposal of municipal refuse is extremely varied. Not only are various methods used in different cities, but sometimes changes from one method to another have occurred in the same city within a relatively short time. A large city on the Pacific slope, within fourteen years, has changed from hog feeding to reduction for recovery of grease and fertilizer, and back to hog feeding. A Mississippi Valley city, during a span of eighteen years, has used reduction, feeding to hogs, and incineration for disposal of garbage. One of our largest eastern cities uses incinerating plants of several designs and dumps some garbage at sea. An adjacent city feeds its garbage to hogs. In some cases such changes may have been caused by necessary adjustment to market conditions, and in others by differing local characteristics. Often, however, the changes are due to an unwise selection of method by the municipality in the beginning. This, in turn, is occasioned by poor engineering, or no engineering, or by over-zealous salesmanship, and, in general, through failure to approach the problem along broad engineering lines. In each case, only by taking full measure and advantage of local conditions can a permanent project be secured. Consequently, in this short paper, only the broadest lines can be sketched.

2. TERMS.

In the United States, refuse is the general term for the solid wastes of a community. House refuse includes garbage, ashes and rubbish. In our cities, these materials are seldom collected together and often are collected in three separate sets of vehicles. Sometimes ashes and rubbish are collected together and less often the garbage and rubbish. For the most part, ashes are disposed of by dumping. Much of the rubbish is also disposed of by dumping, although some is salvaged and some is

burned. Garbage (roughly 75 per cent. moisture and 25 per cent. solids, of which one-fifth is grease) has occasioned the greatest difficulty in disposal, because it cannot be dumped, and other methods must be used. There is very little burning of mixed refuse. House refuse in America is produced in relatively large quantities as follows :

Material.	Average Production in Pounds *per capita* per working year of 300 days.
Garbage	180
Ashes	800
Rubbish	80
Total	1060

There is a large variation in the unit quantities, depending upon the season, the community, the efficiency of collection, and other local causes. Thus, records indicate that American cities have considerably more refuse to dispose of than English and Continental cities.

The methods more extensively used in America are briefly described below.

3. REDUCTION OF GARBAGE.

Garbage reduction is a process in which the garbage is separated into four parts : volatile matter, water, grease and tankage. The amount of grease and tankage so produced and their market value in a typical American city are shown in Table 1. The practice of garbage reduction began in 1886 and developed up to 1915, when it comprised, in general: (*a*) cooking the garbage with live steam in closed tanks ; (*b*) pressing the cooked material ; (*c*) recovering grease by flotation from the liquors and by naphtha extraction from the solids, and (*d*) preparation of the degreased solids into a marketable tankage by drying, screening and grinding. Some difficulties, more or less inherent in the process, were encountered in the control of odours and the prevention of nuisance, depending upon care in operation, character of site, and the general attitude of the community. Nevertheless, under normal labour and market conditions, this method proved to be very economical in the large cities. (See Table 1). Such "older type" reduction plants are now in operation in Philadelphia, Boston, Pittsburg, Washington, Cleveland, Cincinnati, Columbus, Detroit and elsewhere. Half of these plants are under municipal operation.

Efforts to eliminate odours from reduction plants led to the development of the Cobwell process for garbage reduction, which was first used in regular operation at New Bedford, Mass. (1915). In this process, all of the operations are accomplished in one tank. The garbage is first dehydrated or dried by cooking with steam at a temperature below boiling while the garbage is immersed in a solvent, then the solvent is

TABLE I. OPERATION RECORDS OF CLEVELAND REDUCTION PLANT PER TON OF GARBAGE HANDLED.

Year.	Gross Cost.	Percentage Recovery.		Average Price Received.		Total Receipts. (Gross Income).	Net Cost.	
		Grease	Tankage.	Grease. Cents. Per Pound.	Tankage. Dollars. Per Ton.		Profit	Loss.
1905	$1.90	2.63		2.88	$7.05	$2.07	$0.17	
1906	2.39	3.07		3.39	8.45	3.01	0.62	
1907	2.27	3.14		4.27	7.37	3.41	1.14	
1908	2.18	3.44	9.02	4.18	6.30	3.55	1.37	
1909	1.99	3.74	11.3	4.70	7.25	3.59	1.60	
1910	1.91	3.75	13.2	4.31	6.70	4.25	2.34	
1911	1.98	3.53	12.8	4.55		4.08	2.10	
1912	1.98	3.38	11.5	4.10		3.47	1.49	
1913	1.94	3.13	9.7	4.26	6.00	2.97	1.03	
1914	2.54(3)	2.95	10.5	4.17	6.75	3.49	0.95	
1915	1.78	2.81	10.4	4.41	8.75	3.57	1.79	
1916	2.56(3)	3.06	11.2	6.50	7.75	4.98	2.42	
1917	3.40(3)	2.73	11.3	8.00	9.58	5.20	1.80	
1918	3.64	2.37	10.9	13.50	18.50	7.58	3.94	
1919	3.15	2.56	11.6	6.90	11.00	4.86	1.72	
1920	4.38	2.54	12.0	7.55	14.10	5.50	1.12	
1921	4.34(3)	2.93	11.95	3.03	4.25	1.76		2.58
1922	4.57(3)	2.63	9.14			2.44		2.13
1923	2.71	2.37	6.96	4.63	3.86	2.50		.21

Notes :—(1) The gross cost includes only operating expenses except where starred (3) and for these years a moderate depreciation allowance appears to have been included.
(2) The Cleveland plant has been in operation (with several changes) since 1898.

recovered for further use, and, finally, the grease and tankage are prepared for the market. Odours were practically eliminated, and Cobwell plants were built and operated without objection in relatively critical locations at Rochester, New York and Los Angeles, California. In practice, it has been found that these plants are at present relatively costly to build and to operate, without a corresponding increase in the revenue. Consequently, the process has recently been modified to reduce the first cost and the expense of operation.

In the modified Cobwell or Cobwell-Merz system the garbage is first dried (so far in direct-heat driers) and then dried and degreased in the Cobwell tanks, with an increase in the capacity of each tank from 4 to 5 up to 15 to 18 tons of raw garbage per 24 hours. The drying process, however, produces odours more difficult to control,so that more favourable costs are accompanied in part by a greater nuisance hazard. Odours from drier gases have been quite successfully controlled at New Bedford by scrubbing with water and adding chlorine at the rate of about one pound per million cubic feet of drier gases (90° to 100° F). The New Bedford plant burned down in the spring of 1921. The only modified Cobwell plant now in operation is at Syracuse, N.Y. A typical statement of the cost of operation is shown in Table 2.

TABLE 2. ITEMISED OPERATING COST FOR TYPICAL GARBAGE REDUCTION PLANT USING COBWELL-MERZ SYSTEM.

Items.	Cost per Ton of Garbage.	
Operation :—		
Supervision and office	$0.30	
Labour	2.80	
Fuel	1.40	
Solvent	.90	
Power and Light	.40	
Water	.20	
Insurance	.10	
All other Items	1.10	
Total	7.20	
Fixed Charges :—	1.60	
Gross Cost	8.80	
Revenue :—		
Grease	3.70	
Tankage	2.00	
Miscellaneous	.10	
Total	5.80	
Net Cost		$3.00

Other modifications of the reduction process have been made to produce a stock or poultry food, but these have not yet been established sufficiently in regular large-scale operation to permit description in this brief résumé.

4. HOG FEEDING.

Disposal of garbage by feeding direct to hogs is now practised in the following larger cities, among others, and in many smaller ones :

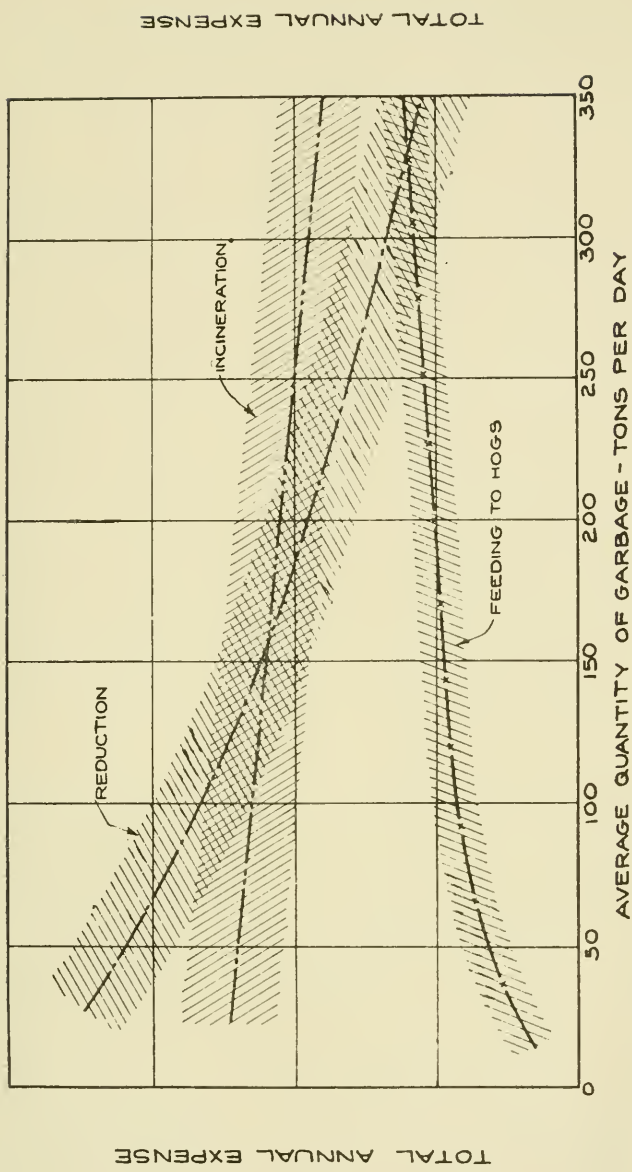
City.	Population 1920	Operation by City or Contract.
Los Angeles	576,673	Contract
Denver	256,491	Contract
Salt Lake City	118,110	Contract
St. Paul	234,698	Farmers
Grand Rapids	137,634	Contract
Buffalo	506,775	City
Newark	414,524	City
Worcester	179,754	City
Brockton	66,254	City

In small villages, fresh garbage can be disposed of by feeding to hogs without the construction of elaborate establishments and without causing undue nuisance. In larger projects, a relatively large investment is required for buildings, land, hogs, water supply and other structures necessary to prevent nuisance and secure continuous operation. Actually, the unconsumed garbage and hog manure amounts to over 40 to 50 per cent. of the garbage, and this residue must be otherwise disposed of. In Buffalo, the installation of a drier plant to dispose of the piggery refuse has been considered.

One difficulty inherent in the hog-feeding method of garbage disposal is the securing of a site. The large area generally advisable (upwards of 100 acres in large projects) makes it necessary to seek a location outside of the city limits, and thus in other communities. Recently, in two larger projects, it has not been possible to secure such outside sites because of the active opposition of the neighbourhood, and other methods of disposal have been forced. In a favourable and friendly atmosphere garbage may be fed to hogs for a very low cost in spite of the longer haul to the hog farm. No unsatisfactory results of the process, in bad pork, or otherwise, have been experienced under reasonably good management. Financially, the method depends on the price of hogs (and back of that, corn).

5. INCINERATION.

Incineration is used in many of the smaller American cities for the disposal of garbage and rubbish. Less frequently, it is used for burning garbage with an auxiliary fuel, and in a few cases for burning mixed refuse (garbage, ashes and rubbish) as is so often done in England.



NOTE.—This chart is not specific, and cannot be applied to particular problems. It does not cover local conditions. It is merely illustrative of general tendencies under certain labour and market conditions. No actual costs are shown on the chart, because they vary in different cities.

Recently, large cities have been building incineration plants. A large number of different furnaces are in operation. Some are developments of early American garbage furnaces comprising drying hearths and grates for final combustion, and using additional fuel ; others are developments of the mixed refuse incinerator (destructor) using a forced draft of pre-heated air. A helpful classification is into "inside storage" and "outside storage" plants.

With inside storage, the collection vehicles drive on to an ample floor just above the furnace tops and discharge directly into the furnace. Practically all of the refuse is thus stored on hearths or special grates inside the furnace and there is no storage in bins or hoppers about the plant. Such plants may be kept free of unsightly refuse, and are less costly to build and operate than "outside storage" plants. They are usually operated only during the hours of collection, but continued for several hours thereafter, to complete the incineration. With "outside storage," the collection vehicles drive to a dumping floor 12 to 14 feet above the furnace tops, and discharge into a storage bin from which the refuse is shovelled into the furnace. This operation permits a closer regulation of the mixture and of the rate of feed to the furnace, with a resulting economy in auxiliary fuel and likelihood of more uniform and efficient combustion.

Incinerators are in operation in San Francisco, New Orleans, Dallas, Atlanta, Charleston, Milwaukee, Trenton and elsewhere. A 280-ton plant is just being completed in Philadelphia, and two large plants (upwards of 300 tons capacity) are under construction in the Borough of Manhattan, New York. For smaller projects and with favourable locations, a simple type of incineration, often with inside storage, appears to be growing in favour. A typical estimate of the cost of operation for burning mixed garbage and rubbish follows :

Item	Cost per ton.
Operation :	
Supervision	$ .15
Labour	1.25
Auxiliary Fuel	.05
Repairs and Maintenance	.20
Total	$1.65
Fixed Charges	.60
	$2.25

6. OTHER METHODS.

The Beccari process, developed in Italy, has recently been introduced in America with a test unit at Paterson, N. J. and a small plant at Searsdale, N.Y. (Population 5,000). It is simple to operate and produces a humus or "worked over" garbage, which is claimed to have value as a fertiliser.

Much refuse, mostly ashes and rubbish with some garbage, is disposed of on dumps. The maintenance of dumps and the securing of sites within reasonable hauling distance are problems which are becoming more serious with the growth of American cities.

7. COMPARISON OF METHODS.

So many special local factors enter into the refuse disposal problem that only general comparisons are helpful. The more complicated machinery of the reduction processes has quite largely confined this method to the larger cities. Hog feeding has been used in towns of moderate size, where advantage can be taken of the low cost incident to an informal method of disposal, and where interruptions in service are not so likely to be serious. At the present time, incineration is being adopted over a considerable range of capacities, from the larger plants in New York and Philadelphia to cities of 40,000 population and under.

Costs also are responsive to local conditions and vary widely. A rough picture of the range for several methods of garbage disposal is shown in Figure 1. The estimated net cost per ton of garbage includes all items of operation and an allowance of 7½ per cent. for fixed charges. Reduction costs range from over $3.00 a ton in small projects to under $1.00 a ton in large projects. Incineration costs vary less, ranging from somewhat over $2.00 per ton in the smaller projects to about that figure in larger installations. Hog feeding, including an allowance for haul to the country, may cost about $1.00 per ton for complete disposal.

8. TENDENCIES AND TESTS.

There is a need in America for more exact and far-reaching data relating to the operation of refuse disposal plants as regards design. There has been too little impartial development of the several processes and types of plant. Much sound data has been secured for the design of sewage treatment plants by the operation for many years of large-scale testing plants, with the result that designs can be made with security as regards the effluent produced in the sewage field. For instance, the Sanitary District has built, upon the recommendation of Mr. Langdon Pearse, its Sanitary Engineer, sewage treatment works at Maywood and Calumet, designed partly to develop design data for use in the larger works. The City of Indianapolis has for the last year been making special tests of a new reducing tank for garbage, and certain manufacturers have devoted much time to creditable development work, which has resulted, for instance, in the Cobwell reducer and other less important advances. Nevertheless, a great deal more engineering data from operation under technical control of small working-size units should be secured. Municipalities could make good use of such information.

9. CONCLUSIONS.

In conclusion, I wish to express my deep appreciation of the honour extended in the opportunity of presenting this brief paper. I have visited many of the refuse disposal works in Great Britain and Europe, and have read and studied the text books and pamphlets. British engineers have pioneered in the disposal of refuse and have pointed the way for much that is good in American practice. My acknowledgment of your courtesy and interest is, therefore, hearty and sincere.

REFUSE DISPOSAL BY SEPARATION AND SALVAGE.

By James Gair.

Highways Engineer, Metropolitan Borough of St. Marylebone.

It is not necessary in this short paper to elaborate the necessity or importance of the work of disposing of house refuse by sanitary and economical methods. It will generally be admitted that, especially in large communities, these are matters of first importance. From a sanitary or public health point of view, as well as from the view of the ordinary citizen, both these essentials of refuse disposal should be observed.

Looking back on the general situation prevailing in England and Wales at the date of the "Return as to Scavenging in Urban Districts," issued by the Local Government Board in 1914, out of 482 towns between 5,000 and 20,000 population there were only 71 towns with destructors, 318 towns using tips or dumps, and out of the 96 great towns (excluding London), 72 owned destructors, but only 25 disposed of all their refuse by this means, 24 being without destructors, 61 using dumps to a greater or less extent, so that dumping was broadly speaking the general means of disposal.

It was then stated as regards dumping that "the use of tips sometimes merely perpetuates and concentrates those evils which arise from the storage of refuse in the neighbourhood of dwellings. If a tip is to be tolerated it should be situated in a place remote from dwelling-houses, and the refuse should be covered with earth as soon as it is deposited." Everyone interested in Public Health will concur with the view thus stated, and the Ministry of Health, in 1922, arising out of a series of meetings on the question of tips, issued a circular setting out the precautions to be taken where refuse was deposited on land, but it is extremely doubtful whether the suggested precautions have been generally adopted.

The report further states that "the satisfactory disposal of the refuse creates very difficult problems, especially in the large districts."

It is difficult to compare the situation to-day prevailing with that of 1914, owing to the lack of available statistics, but comparing the position of refuse disposal with that of sewage disposal, in 1919–20, the annual cost of sewage disposal in England and Wales was £6,355,510 (including loan charges), the outstanding loans being £40,370,557. The annual cost of disposal of house refuse was £7,500,000 (including loan charges), the outstanding loans being less than £5,000,000. The capital expenditure on refuse disposal was therefore comparatively small as compared with sewage disposal. Refuse disposal has made little progress from a sanitary point of view, compared with the scientific and general advance made throughout the country as regards sewage disposal, for this field has been one of steady progress since the passing of the River Pollution Act of 1876.

A general improvement in refuse disposal methods is likely to be slow, unless more drastic measures are enforced as regards dumping, and apparently to-day the position of affairs (except in a few instances) remains unaltered. This particularly is the case as regards the Metropolitan boroughs, for the final report on the Conference of Metropolitan Borough Councils on refuse disposal, dated December, 1921 (convened by the Westminster City Council), states that of the 1,500,000 tons of refuse collected annually in the London area, 80 per cent. is still disposed of by means of dumping. The destructor has evidently not been able to establish or maintain its position as an effective means of solving the difficult problems referred to in the Local Government Board's 1914 report, owing to its failure to fulfill its proper function as an effective means of utilising the inherent calorific value in the refuse, and not merely operate as an incinerator. The question, therefore, that has been exercising the minds of those responsible for this work, has been to endeavour to find some other sanitary and economical method of disposal.

Consequently, arising out of experiences during the war period, during the last six years there has been a gradual change of view from mere destruction towards salvage or utilisation. Closer attention has been given to obtaining more accurate data as to the composition of the refuse to be dealt with, and the uses and values of its various constituents, and gradually mechanical means have been applied whereby the various constituents can be eliminated or separated from the bulk of the refuse, with the result that a number of cities and towns have now installed separation or salvage plants as a means of dealing with the disposal problem.

At Sheffield a plant has been constructed to deal with the house refuse by a screening and fuel recovery process, capable of dealing with 300 tons of house refuse per day. The refuse is delivered by means of electrically operated grabs into feed hoppers fitted with conveyor plate bottoms which carry the refuse forward at a regular rate of speed into rotary screens. These are ten in number, each screen being 30 feet in length and 5 feet 6 inches in diameter; the first 15 feet of each screen consists of ½ inch wire mesh, which is surrounded by an outer envelope

of $\frac{1}{4}$ inch mesh, and the latter 15 feet consists of $1\frac{3}{4}$ inch mesh. Each screen is separately driven by an electric motor, so that any screen can be run quite independently of the others.

The refuse is thus separated into (*a*) fine dust (45 per cent. of the bulk); (*b*) fine cinder (18 per cent.); (*c*) coarse cinder (10 per cent.). The large material or tailings equal to approximately 25 per cent. is deposited on to a travelling belt from which paper, tins, rags, bones and other saleable materials are picked off in passing on to incinerator furnaces, the hot gases from which are carried through the boiler and thus assist in steam production. The fine dust is sold for fertilising purposes. The fine cinder after passing over a magnetic separator to remove nails and particles of iron, can then be either loaded direct into barges, or trucks, or carried forward to a briquetting plant, where it is mixed with the necessary percentage of pitch and converted into fuel briquettes for domestic use or steam raising purposes. The coarse cinder passes into a series of washers in which the water is forced through the material as it lies on a sloping grid, the lighter material or fuel content being separated by specific gravity fron the heavier incombustible matter. This washed material is conveyed into overhead ferro-concrete bunkers in front of two Sterling water tube boilers, each with a capacity of 15,000 lbs. of water per hour which are fired by underfeed travelling grate stokers, on to which the washed cinders are fed from the storage bunkers. The steam is super-heated and supplied to three 250 k.w. D.C. steam-driven dynamos which provide the necessary power for running the plant, and for charging the electric battery-driven vehicles which are used to collect the house refuse. During the first six months of operation recently completed, 3,600 tons of fuel were sold apart from the works' use (no coal whatever being used on the works), and 28,291 electrical units were generated for charging of batteries of collecting vehicles. 427 tons of tins, equal to 1.2 per cent. were sold, also 30 tons of nails, 74 tons of paper, 18 tons of rags and 6 tons of bones.

The Westminster City Council have recently installed a salvage plant to deal with 100 tons of house refuse per day. In this plant the refuse is delivered from the collecting vans immediately over a large steel hopper, and thence on to a 30 inch belt conveyor. From this belt, rags, bones, bottles, etc., are picked off by hand. At the end of the belt is fixed a magnetic separator for removing tins and iron. At the point where the material is discharged from the belt conveyor into a revolving screen, a specially designed patented paper extractor is fixed, by means of which the loose paper is lifted from the belt by suction, delivered by means of pipes into a dust separator, and thence direct to a paper baling press.

The material delivered into the revolving screen is divided into three sizes, two of which are conveyed to washers, where the heavier combustible materials are eliminated. The third portion passes through the screen and is discharged into a chute and delivered direct into a pulveriser which produces a material suitable for utilisation as a manure.

The report of the Comptroller of the City Council on the working of this plant during the recently completed six months' trial period shows that, despite the drawbacks inevitable with the operation of a new plant, a saving has been made against the cost of disposing of the refuse by barges under contract.

At Newark, a small but most successful salvage plant has been working on similar lines to the foregoing, and during the year ended December, 1923, a total of 5,967 tons was collected. Of this, 2,175 tons were sold, providing a revenue of £723, the remainder being burnt in a destructor. The nett disposal cost per ton was only 2s. 3d., surely a record figure for an inland town.

At Birmingham, in April of this year, a salvage plant was opened to deal with 100 tons of refuse per day. The distinctive feature of this new unit appears to be the application of pneumatic appliances for material conveying. The refuse is fed into a rotary screen which screens out the fine dust, estimated at 50 per cent. of the total bulk. This fine dust which is suitable for agricultural purposes, is conveyed in iron pipes to delivery point by air pressure. The material or tailings passing over the end of the screen falls on to a picking belt from which saleable articles can be picked. The paper is taken off the picking belt by means of an air suction plant, cleansed and delivered ready for baling. The tailings are then delivered into storage hoppers adjacent to the feed doors of the destructor furnaces which provide steam for the electricity generating plant, supplying current to drive and light the works and for charging the electrically propelled dust collecting vehicles.

At Marylebone, a separation or salvage plant has been working since 1920, for the design and running of which the author has been responsible. The Borough Council having taken over the work of collecting and disposing of the house refuse, decided that dumping should be discontinued as soon as possible. This plant has been designed to deal with 160 tons of refuse per day. The refuse is fed into a rotary screen from a collecting pit by means of an electrically driven crane. This screen is 30 feet long, 8 feet in diameter, and is mounted on ordinary standard type rubber tyred wheels. The first 20 feet is perforated with ½ inch perforations, the last 10 feet with 2 inch perforations. By means of the first section, the fine dust is extracted and this, during the winter months finds ready sale to brickmakers (for mixing with the clay). The larger sized material which contains the cinders or breeze, despite a proportion of small paper, vegetable matter, clinker, broken pottery, etc., is also used by the brickmakers for burning bricks or, if required, is washed in a rotary washer to eliminate the heavier incombustible matter. In this form it is sold as a fuel for steam raising to market gardeners and laundries. The larger material passes through the screen on to a picking belt from which paper, rags, bones and tins are picked off by hand. The debris is then delivered to the stokehole and burnt under a "Babcock" boiler which provides steam for running the plant which is all electrically driven.

During the year ended 31st March, 1924, 40,174 tons of refuse were dealt with, of which 13,580 tons were sold as under .—

Ashes and breeze	12,147	tons.
Waste paper	610	,,
Old tins, etc.	387	,,
Rags and bones	107	,,
Miscellaneous	329	,,
	13,580	,,

producing a revenue of £4,945. The nett cost of disposal being approximately 7s. per ton. Any description of the Marylebone plant would be incomplete without reference to Mr. J. T. Watson, M.B.E., Chairman of the Highways Committee, 1917 to 1923, whose work in connection with salvage during the war, and also with the whole question of refuse disposal in London, is well known.

At Marylebone, the chief difficulty is to find a suitable outlet for the fine ashes or dust during the summer months when the cinder content is practically negligible, and consequently unsuitable for brickmakers, only a limited market being obtainable for this product as a fertiliser. During the winter months when the cinder or fuel content is high, there is no difficulty in finding a market for all the ashes and breeze that can be produced.

The fundamental idea in all utilisation plants apart from the recovery of marketable products such as paper, metal, rags, bones, etc., is the recovery of waste fuel content mainly in the form of cinders (which would otherwise be lost) in such a form as to be readily available for steam raising purposes, and when it is remembered at what cost in the form of coal these cinders are produced, if viewed from that point alone, salvage needs no justification, for fuel in whatever form it may be available is certainly one of the essentials of our civilisation.

The large debris from a screening plant can be burnt in a suitable form of incinerator, leaving the fine ashes or dust to be disposed of as a fertiliser, or this can be dumped without risk of creating a nuisance. Until some form of furnace is produced capable of dealing with the heterogeneous mass of refuse and of enabling the calorific value of the refuse to be available in a reliable and efficient manner, salvage plants appear to be the only alternative to dumping. Many sanitary engineers consider that this can only be done by some form of vertical or blast furnace type of destructor, similar to the Didier destructor at present in use on the continent, and whose steam producing abilities appear from the reports available, far ahead of the ordinary type of destructor giving a 60 per cent. overall thermal efficiency. In an age when science has enabled man to communicate between continent and continent in the twinkling of an eye or the space of a few hours by aeroplane, it seems

incredible that the calorific value of London's refuse, equal to 5,000 tons per day, should remain unutilised for, taking the modest figure of 2 lbs. of steam per lb. of refuse, or 10,000 tons of steam per day of 24 hours, this equals 416 tons of steam per hour and gives 100,000 k.w. per hour, an output approximately equal to that of Lots Road Underground Railway Electricity Works. To find sanitary and economical methods whereby this vast tonnage of material can be utilised for the common good is the task allotted to sanitary engineers.

DISCUSSION.

Mr. J. C. Dawes (Ministry of Health) said he would confine his remarks to a few observations on the paper prepared by Mr. Greeley. American practice obviously differed in some respects from English practice, and some of the differences were very interesting. Mr. Eddy had already pointed out that America produced *per capita* much more sewage than we produced in England, and the same thing applied with regard to dry refuse. The refuse yield in America was said to be 1,000 lb. *per capita* per annum, but we found that when an English non-mining town—the figures, of course, are altogether different for coal mining areas where the miners receive a special coal allowance—was yielding more than 500 lb. *per capita,* there was something remarkable about the place. In this country it was considered that 500 lb. was too high a figure, and some districts had introduced interesting publicity schemes to try and get below this amount. Just before coming to the Conference he had received a letter giving him some of the results of a publicity scheme in Cleethorpes, where they had succeeded in reducing the amount to considerably under 500 lb. *per capita.* He thought it would be interesting to ascertain what effect the multiplicity of bins had upon the amount of refuse produced. In Britain the dual system was not used at all; it was possible that the yield bore some relation to the method of storage at the dwelling-house.

Incidentally, he would remark in passing, that there were very few piggeries associated with cleansing departments in Great Britain, and these were small, and it was rare to find one with 150 pigs at any time. Garbage reduction was not practised in England, although the country was said to be suffering from a greatly diminished pig population, and probably there was nearly sufficient organic material in house refuse to bring the pig population up to what it ought to be. The question was whether reduction could be carried on economically. From a municipal point of view, this was extremely doubtful, except in districts where there were large hotels, and in such areas the producers sold the garbage direct to pig keepers so that it never became refuse. Returning to the question of the dual bin system and its effect on the yield, he said that where a bin 28 inches high was used in England a different result was obtained from that recorded in a district where the bin was 24 inches high. Large bins had the same effect as a multiplicity of bins; both were invitations to increase the quantity of refuse, and made necessary occasional campaigns designed to impress upon the public the need for keeping down the amount of house refuse to a minimum.

In a brief reference to refuse disposal work, he said that eight distinct methods of disposal were in use in England because of the variation in local conditions. The Ministry of Health took the view that prior to erecting disposal plant a local authority should first of all obtain a series of seasonal analyses of the refuse to be treated, because in some districts the fuel content might be as high as 40 per cent, and the putrescible content as low as 7 per cent, whilst in others the figures might be

15 and 30 respectively. In between these limits all kinds of figures were reported.

Obviously a plant designed for high fuel content must differ from one with low fuel content, and the same applied on the putrescible side. Where the refuse contains fæcal matter and has a heavy moisture content, other modifications are usually required. The quality of "dry" house refuse varies with the proportion of gas fires in use, and it is an interesting study to observe what a difference gas fires make in the yield, quality, and calorific value of house refuse.

Mr. Gair had pointed out in his paper that in some districts the refuse contained up to 35 per cent. of fuel, and it was interesting to observe that in the north of Scotland the fuel content was about the same as in the middle of England, and the refuse from the middle of England was rather lower in fuel value than was the case in some places in the west of England. On an average 75 per cent. of English house refuse (dry) was definitely mineral in character, and the question as to how far we should waste the calories in the 40 per cent. fuel by attempting to raise the temperature of the dry dust to incandescence was always one of considerable local importance. Mr. Gair had dealt with the mechanical separation of these two refuse contents. The breeze or cinder found in English refuse often had a B.T.U. value of 8,000 to the lb., but taking cinder and dust together the average figure was under 5,000 B.T.U.s per lb. ; an important difference from a raising point of view when the greatest possible evaporative value is desired.

It was well known that electrical engineers were not at all sympathetic to the use of steam generated from house refuse, and the 5,000 B.T.U. per lb. figure probably explains why.

It is rather unfortunate that the two countries are without agreed technical definitions as applied to cleansing work, because at present it is impossible to tabulate the data of one country under the headings used in the other. For instance, incineration in America is often compared with separation in England, but the two methods are not strictly comparable.

More research is desirable into the cause of the troubles associated with refuse dumps. The putrescible content explains the presence of rats and flies, but does not explain the presence of fire although given fire it explains the odour that comes from it. Another interesting point was whether the presence of 10 per cent. (the English average) organic matter makes the incineration of 100 per cent. necessary, or whether it might be more economically dealt with separately though not separately collected. Still another aspect calls for investigation. What is the highest possible evaporative figure for dustless refuse or "tailings"? There are a few plants in England where a steady two and three lb. of steam per lb. of "tailings" is now reported. Personally, I think this point should be taken up seriously because steam supply capable of effective regular work is still a matter of importance.

Whilst the conference had been discussing the troubles associated with sewage sludge—and they are many and very difficult—he had been thinking how extremely pleased the officers on the "dry" refuse side—the cleansing officers—would be if they could liquefy house refuse and make it flow through pipes. There would be more problems, but they would be glad to face them. At present, however, pipe line work was limited to the removal of the fine separated dust from the storage hopper to the barge, truck or land as the case might be.

In the new Birmingham scheme about 40 per cent. of the refuse was passed out through a pneumatic main, and this material, in the form of dust, was said not to encourage rats or flies. Also it was claimed that there was nothing in it to fire or cause offensive odours.

Another method of disposal, not referred to by Mr. Greeley, was that known as pulverisation or crushing. It has been found in a few districts where the land required the physical effect to be obtained from a granular material, that crushed refuse could be used with advantage. By crushing it was possible to get down the organic material to very small particles, mix them with the mineral particles, and so produce a mixture said to be unattractive to flies or rats. Rabbits had been known to burrow in crushed refuse, but so far there had been no reports about rats, and the mixture had not been known to fire. There were districts where this method had proved a solution of the local problem. In a Lancashire town, practically the whole of the refuse from 60,000 people was pulverised and disposal of at a total cost of 1s. 6¼d., per ton after sending the material by rail to farms forty miles from the town.

When Mr. Greeley suggested a disposal figure of about 10s. per ton it almost frightened us. Many towns in England would not like to think they had ever again to face figures like that, but local conditions were and must remain the controlling factor in efficiency and cost.

In Dundee, a city of 200,000 people, it was reported that there was no difficulty in selling ordinary dry refuse after the removal of metal containers and glass bottles, and the city receives several thousands of pounds for its refuse every year. There can be no doubt that where the land is heavy, house refuse can be made to serve a useful purpose, but care is required to avoid nuisances.

Mr. J. A. Priestley (Sheffield) said that the question of disposal of refuse was one that had received a very great deal of attention in this country during the last few years, and a very different atmosphere prevailed in reference to the question than was the case six or seven years ago. Most local authorities were now approaching the matter with a view to seeing what there was in the refuse that they could make use of, with the idea that instead of destroying or dumping refuse they could derive something from it in the way of fuel or material which could be used for re-manufacturing purposes. On these lines all refuse disposal plants at the present time were being more or less constructed. It was a very significant fact, that, in this country, we had a product of about

5 cwt. per head of population per year of refuse that consisted of 40 to 45 per cent. of fuel. It had dawned on many people that to simply waste that fuel by putting it through furnaces and destroying it, without obtaining any result, was uneconomical and extravagant. The object of the plant that had been put down at Sheffield, and operated now for nearly twelve months, was to obtain from the refuse all usable materials, so that the constituents of the refuse could be applied in the most suitable and economical form, rather than destroy or dump it. The results that had been obtained from that system were very much better, and worked out much more economically than from the system of destruction by the old fashioned type of refuse destructor, although it was not cheaper than the method of crude dumping. But everyone was agreed that the system of crude dumping was an impossible one. It could not be justified on any grounds, either sanitary or otherwise, and that fact was very much emphasised when you found that in the last ten or a dozen years, any local authority that desired to continue the system of dumping looked out very carefully for a tip or dump in the district of their neighbours, and not of their own. There were constituents in refuse which could be economically used, and the development on those lines was, he thought, what we had to look forward to. One other point was the apathy which existed with reference to the full utilisation of some of the material available. He referred more particularly to waste paper. There was produced in this country, annually, many hundred thousand tons of waste paper which was either dumped or burned, and which, during the war, was successfully used in the re-manufacture of paper. Now, it was less trouble to use wood pulp and, therefore, waste paper was finding very little or no market, and he thought it was no credit to us as a nation, that a material which had been proved to be of use, should find no market simply because its use entailed a little more trouble.

A vote of thanks was passed to the authors of the papers that had been read.

NATIONAL CONTROL AND ALLOCATION OF WATER SOURCES.

By Percy Griffith.

1. Of all the branches of sanitary engineering, none is more suitable for discussion at an International Conference than that of water supply. As regards the subsequent treatment and disposal of the water, when polluted by domestic or other use, practice varies in different countries to a considerable extent, but in regard to the reservation, collection, and delivery of water from natural sources to consumers' premises, practice can only vary within narrow limits. As, however, the author proposes to confine his attention to the conditions regulating the allocation of water sources, it will be evident that such conditions must be essentially the same in all countries; and while he has for some twenty-five years been closely studying the peculiar defects of British practice in regard to allocation, he now proposes to direct attention rather to the basic principles which must primarily determine the procedure in all countries than to peculiarities of any one of them.

2. Although water is universally required for what is termed "domestic use"—and in this island and other countries under British government or control such demands are predominant—it must not be forgotten that water is essential for other than sanitary purposes, and that in some countries the quantities available are so largely in excess of the demand for such purposes that schemes of allocation must provide for demands based upon economics as well as those based on health. It is with this in view that the author claims natural sources of water as a national asset—that is, as a "property" in which the interests of the community at large must take precedence over those of the individual.

3. If we accept this as a basic principle, it does not, however, necessarily follow that water must be regarded as national property to be *owned* by the State. Without attempting to decide the relative merits of the two alternatives, the author merely points out that national control is a valid alternative to State ownership, with certain advantages which cannot be overlooked or neglected with impunity. Here, in England, we have erred rather on the side of individualism than on that of

Communism, and although the error has not seriously prejudiced the health of the people, we cannot claim to have solved the problem of allocation on economic lines. It does not follow, however, that our economic errors would be solved by a policy of communal or State ownership of water sources, and the author goes no further than to claim the necessity for State control of allocation.

4. Now, apart from vested interests—that is to say, " rights " claimed and exercised by virtue of custom rather than natural laws (usually designated " common law rights ")—it would undoubtedly be much simpler for any State to declare all natural sources of water State property and then to provide administrative machinery or procedure for allocating such sources on some uniform basis ; but, on the other hand, water is almost the first natural product utilised by the settler on virgin soil, and long before a new colony requires the solidarity and coherence of a State the most convenient sources of water have been secured by individual landowners for purely personal use, so that a declaration of State ownership, unless decreed by an imperial statute prior to the colonisation of unoccupied areas, necessarily involves the purchase or alienation of previously acquired " common law rights." It seems, therefore, preferable to proceed by way of State control rather than State ownership, and this involves the necessity for prescribing a limit to the claims of landowners as regards water sources.

5. This limitation of individual claims must, however, be based upon some basic principle, and an International Conference such as this appears to afford the most suitable opportunity for a discussion of the basic principle which would most equitably meet the necessities of the case. The author submits for discussion the proposition that a landowners' rights in water sources on, under, or contiguous to his land should be limited to such a quantity of water as may be reasonably necessary (*a*) for the health of the residents on his land, and (*b*) for the economic development of that land, having regard only to its natural resources and not to its commercial use for purposes independent thereof. The use of larger quantities of water, or of water for other purposes, would then involve a specific allocation by the State, and the payment of the cost involved in such allocation, *but no payment for the water as such.* Here we see the advantage of State control rather than State ownership, in that there would arise no temptation to make a natural product a means of indirect taxation.

6. It may be of interest, if only to facilitate discussion, to consider some of the practical effects of such an enactment. It would at once prevent a landowner from selling the water on, under, or contiguous to his land to other owners or residents on other properties. While it would enable the landowner to charge his own tenants either (*a*) a higher rent for properties having natural sources of water supply, or (*b*) for water supplied by artificial means, it would prevent the tenants from exploiting water sources for purposes of profit because the tenant would have no other rights in the water than those possessed by the landlord.

Water required for irrigation, gardening purposes, or stock-breeding, as well as that required for the health of the residents, would be at the disposal of the landowner ; but neither landlord nor tenant could abstract water for manufacturing purposes unless with the authority of the State, obtained at his own cost. No doubt disputes would arise which could only be settled in the Law Courts, but with the basic principles thus defined, most cases would be capable of settlement without any legal aid, and upon such a basis State allocation could be organised without difficulty. *Without it, however, State control and State allocation would be alike impossible.*

7. The conditions referred to in the last paragraph do not, however, clearly establish the position as regards the use of flowing streams for power purposes, and as State allocation involves the question of " compensation water " (a question in which claims for water-power bulk very largely), it is necessary to consider this somewhat more fully. In a thickly-populated country such as this, streams are very generally utilised by individual landowners for operating saw-mills or other machinery required in connection with such land, or for pumping water or generating electricity used on the particular estate, and as the use of this power in no way affects the flow of the stream or (under normal conditions) the interests of landowners above or below the power-station, it may be reasonably claimed that such " user " (as distinguished from " abstraction ") is fairly attachable to the landowner. But it is by no means equally obvious that the use of the water power for grinding corn, or for other commercial purposes carrying a profit to the owner independent of that derived from the sale of the produce of the land, should similarly attach to the landowner as such.

8. As we are now dealing only with the question of allocation, we shall defer the consideration of monetary compensation due to landowners when the flow of the stream is reduced by the abstraction of water higher up the stream. The author is here only concerned with the point that water-power should not be regarded as a " common law right " of a landowner except so far as it is used for purposes essential to the development of the land as such. Its use for other purposes should involve a specific allocation by the State, as previously suggested in connection with the abstraction of water. Of course, in any country where such rights have been exercised unquestioned, an enactment of this character would involve a provision for monetary compensation, to be paid when the water was allocated to some other purpose. But the erection of new power plant should be prohibited except in cases where the water power is allocated by the State for the purpose ; moreover, all existing power works should be compulsorily registered, with sufficient details as to the amount and the use of the power, to prevent their subsequent extension without authority from the State. The object in view is, of course, to prevent the exploitation of natural sources of water for private profit or for the sole benefit of the individual landowner, except with the specific sanction of the " State."

9. It will be seen that this *simplification of the basic principle* underlying the allocation of water sources involves a *complication of the administrative machinery* necessary to carry it out in practice. But while the author cannot speak for other countries, he does claim that in the British Isles this complication is more apparent than real *as compared with the present system.* Here, while landowners are free from restrictions in regard to underground water, and are only restricted in regard to surface waters by the (contingent) opposition of other landowners who are prejudiced by their operations, the use of water for any communal or public purpose, whether sanitary or economic, involves procedure of the most complicated and expensive character. The author contends that the establishment of a Central Allocating Authority appointed *ad hoc,* and provided with competent technical advice, should be a national charge, and that the expenses incurred in making each particular allocation (to be borne by the applicant) would then be less than they are at present. These expenses would, in fact, be shared by all the beneficiaries instead of being borne solely by the larger authorities concerned, because each particular source would be allocated on a wider and more final basis than is now the case.

10. It is now necessary to point out that such a proposal does not involve (as has been erroneously suggested) the prior tabulation of all the available sources. The principles upon which allocation is to be effected, including the priority or sequence of various claims to water, having been determined, the amount and other essential conditions of each source would be investigated as applications for allocation were dealt with by the Central Authority. But, on the other hand, some general provision could and should be made for the establishment of rain-gauges and the recording of daily rainfalls, also for the regular gauging of the smaller streams. This also might be, at first, a national charge, but the revenue from application fees would probably provide a sufficient sum to refund the amount so advanced. Such questions of detail can, however, hardly be considered of international interest, and the author, therefore, goes no further than to claim that the National control of water sources is a matter of national interest, and the initial cost, at least, should be a national charge.

11. As regards the administrative machinery involved in the proposal, the author has already made specific suggestions applicable to Great Britain and Ireland, these being based upon the recommendations of an Expert Committee appointed for the purpose in the year 1918, but these would have no interest to our guests from overseas. It is obvious that each watershed should be dealt with as a whole so far as its surface supplies were in question and required to be allocated. But as regards underground supplies, and even surface springs, the method of subdividing the research work involved in allocation is a matter for discussion. In the former case (underground water) it seems necessary to define a " source " empirically as one the yield of which is not affected by abstraction from another " source " even in the same stratum. The

elaborate records prepared by the United States Geological Survey, as well as our own less complete records and general experience, alike indicate the impossibility of forecasting (apart from local experiments) the extent, nature, and direction of flow of deep-seated water supplies derived from distant outcrops. All such "sources" (wells and borings) should, however, be compulsorily registered with records of the quantities abstracted from time to time, and the results as regards pumping-levels, if only for the purpose of arriving at the general laws which actually determine the results, so far as this may be possible.

12. It will thus be seen that the Central Authority entrusted with the allocation of water sources would require to maintain a Statistical Department of considerable magnitude and having an expert *personnel.* The information thus collected would, however, have a cumulative value extending far beyond the interests of any one locality, and, in course of time, the staff could be reduced as the work became more standardised. The author agrees that such a reduction is rarely, if ever, accomplished in Government Departments and, therefore, it would not be safe to rely upon it, unless Parliament intervened to limit the expenditure from time to time. On the other hand, if the statistical and other records were open to public reference, the public interests would be served to an extent proportionate to the cost.

13. A more important point arises, however, in the fact that allocation implies *allocation for a particular purpose,* and to prevent the use of water sources for purposes other than those for which the allocation is made, continuous control is essential. This control does not necessarily imply continuous supervision, because State intervention would only be necessary in cases where water was scarce and other interests were prejudicially affected. The initiative could, therefore, rest with such "other interests," and the element of bureaucratic interference, which is admittedly very objectionable, could thus be eliminated.

14. The whole question is one which must be discussed on broad lines, having regard to all interests involved. Thus it is not one which can be settled satisfactorily by either politicians, engineers, or departmental officials alone. Collaboration between all these interests is essential, and legislation must not be regarded as a matter of party politics, but as a question of commonsense administration of a valuable national asset. Perhaps our visitors may be in a better position than ourselves in securing useful legislation of this kind independently of party issues, and, in this case, their advice will prove most valuable.

15. As a final point for discussion it may be worth while to invite views as to the extent to which State control should cover the question of the *economical use* of water. The quantities required for sanitary purposes vary to an enormous extent in different countries and even as between different towns, and it is an open question whether State control of sources should imply any limitation of the consumption for such purposes, and, if so, how such limits should be determined. Moreover, it is the usual practice to supply water for many other than purely domestic purposes without any attempt to measure the consumption

of each consumer, and, apart from the objection to limiting the consumption for sanitary purposes, there arises the difficulty of providing meters on the large scale which limitations would involve. The author ventures to suggest that an occasional measurement of any consumer's rate of consumption might meet the case sufficiently to prevent waste without the provision of fixed meters to all services.

16. Closely allied to this question is that of the purification of otherwise doubtful supplies in order to render them available for domestic use. In the case of London, very valuable experience has been obtained as to the possibilities in this direction. Some fifteen or twenty years ago public opinion and expert advice agreed in the demand for a pure supply being obtained from the Welsh mountains, but at the present time the exhaustive researches carried out by Sir Alexander Houston for the Metropolitan Water Board have produced an almost universal concensus of opinion that very unsatisfactory sources can be safely utilised if due precautions are taken as regards the collection, storage, and treatment of the water. Similar results have been accomplished by Mr. Caink at Worcester and by other water engineers, so that it is no idle fancy to suggest that an intelligent system of purification may provide the means for utilising sources which would be otherwise wasted. The question of waste is not, therefore, confined to consumption and distribution, but must be also considered in connection with the utilisation of sources formerly regarded as unsafe for public domestic use.

17. No doubt many problems other than those herein mentioned will arise in course of discussion, but the author's purpose has been to urge the necessity for regarding natural water sources as a national asset, and for providing, in every self-contained "State," such administrative machinery as may be necessary to enable the "State" to allocate all water sources in the best interests of the State as a whole. The adoption of some basic principles, as regards priority of claims, and the natural "rights" of landowners, as well as the establishment of a competent and permanent (non-political) "authority" to deal with the whole question on equitable and uniform lines, would, it is contended, prove in the end an economically-advantageous proceeding, notwithstanding the initial difficulties and expense it would involve. Incidentally, it would lead to a solution of the vexatious problem of "consumption" (in both water and money), in that it would bring claims forward in terms of particular and actual, instead of general and hypothetical, interests. At present compensation is only provided (in this country at any rate) to the bed of a stream and not to any personal interest; in fact, it is frequently the case that the power provided by compensation water is actually larger than that provided by the stream flowing under natural conditions—that is, with extreme and, perhaps, violent fluctuations in the rate of flow. The present conditions, as regards springs and underground water, are also (in this country at any rate) utterly unworthy of a civilised nation. Hence a free discussion on the broadest lines cannot fail to be of international interest, and to justify the author in having, even imperfectly, suggested material for discussion.

DISCUSSION.

Mr. R. G. HETHERINGTON (Ministry of Health) said that he had gathered that the paper advocated a general allocation of water resources by a central authority which was described as *ad hoc*, and non-political. He took it that any authority which was dealing with the allocation of water—a matter needing legislative authority—would have to be subject to Parliament, and some minister would have to be responsible for it, and in that sense it would be political. One point he would like to raise was this: if you put an *ad hoc* central authority in charge of water, and water alone, you lost the co-ordination which had been found essential in the sanitary services of a district. If, to take one example, you divorced the supply of water from the removal of that water after it had been used and becomes sewage, you raised various difficulties. The finance of Local Authorities was such that you could not shut your eyes to the need of work other than water supply in the consideration of what was in the range of practical politics and what was not. Of course, it had to be borne in mind that although we had not got a central *ad hoc* water authority in this country, we had within recent years built up within the Ministry of Health as the main authority a distinct water supply department, which had now got an advisory committee drawn to a considerable extent from outside sources, which advised the minister on all these matters. The outside members of this committee were at least free from the terrible blot of being bureaucrats. There was difficulty in keeping an authority entirely centralised on one subject without taking cognisance of the others, and the modern tendency was that the central authority should have outside help brought in on specific subjects. It would be interesting if we could hear to what extent allocation of water resources existed in America.

Mr. FULLER (American Public Health Association) said that in America there were perhaps six or eight of the States along the Atlantic seaboard where there were various jurisdictions. These were sometimes designated as State Conservation Commissions, in other instances they were called State Water Boards, and in yet other instances they were known as Departments of Conservation and Development. But under that general style of nomenclature there were gathered together several different lines of inquiry. In New York State there was a State Conservation Commission, and it was necessary under a law for each local authority to make application to that State Commission before it had the right of entry to go forward and develop any water supply project. That meant that the city of New York, going into the Katskill Mountains, as it had recently been doing, to collect the streams on the northern slopes and bring them into its water supply, was obliged to make formal appearance, and there had to be adjudication between the rights of the city of New York and those of smaller communities like Schenechtady, which were looking forward for several generations as to what their needs might be. He thought this a very wise undertaking. It was of necessity a

State and not a Federal undertaking, the sovereignty being vested in the individual States, and the Federal authority only being involved if the rights of more than one State were affected. New Jersey had gathered together a great many statistics bearing on the question, but there were so many prior rights associated with the bulk of water power and water supplies owned by private companies that the situation was very complex, and he was very much impressed with the need of getting these undertakings under way at as early a date as possible, and he had a keen appreciation of the fact that they seemed to become more and more difficult to negotiate as time went by. The small undertaking could be got through without great difficulty, but it took time, and this frequently worked to the disadvantage of the small community as against the large city. If one went to the other style of treatment and attempted to get a programme laid down for a long term of years ahead, as in the case of New Jersey, things became complicated, and seemed to be associated with the rights of so many different parties at interest, that the undertaking seemed to be swallowed up for a number of years. But he believed that this adjudication of the water rights was something that must be faced if there was to be an equitable treatment of this style of undertaking, and in the different individual States the problem was most pressing and recognised more and more every year. Attempts were being made to develop inter-State treaties, some rational programme by which undertakings where the watershed was in more than one State could progress. There ought to be set up a line of action through the Federal Courts which would allow of compensation to property owners and adjudication of the rights of different States dependant on the area in each State in which the water collected. It took a long time in America to get these matters adjudicated equitably, and in a practical way.

Mr. Binnie (the Chairman) asked a question about compensation water. He said the practice in this country, if a stream or river was being impounded, was to give out a certain proportion of the flow as compensation water down the river. There were certain empirical rules which were adopted by Parliamentary Committees, and these varied according to the nature of the particular stream. This compensation water was taken as full compensation to all the riparian owners of water between the reservoir and the sea, and he would like to know whether in the United States water compensation was given in the same way, or whether they settled by money compensation to millowners and others whose rights were interfered with?

Mr. Fuller said that money compensation was usually given and water compensation was rather exceptional.

Mr. Binnie (the Chairman) said the matter would have to be reconsidered in this country. The resources of water supply were becoming

scanty, and the compensation given down stream was a serious consideration.

Mr. FULLER said that privately-owned waterworks enterprises were more likely to be liberal in the use of compensation water than were municipal-owned waterworks enterprises. He thought there was almost invariably an effort made to have water released on a stream bed to the extent of the flow of the driest month of the year. But, generally speaking, municipalities had to face the money compensation.

Mr. BINNIE (the Chairman) said that with regard to the question of allocation, the system of inquiry before a Parliamentary Committee in this country had not worked very well in the past in certain respects. When a proposal was brought before a Parliamentary Committee, that Committee was confined to the merits of the particular scheme, and a wider outlook was not taken as to whether some other scheme might not be a better way of supplying that particular community, or whether it would not be more satisfactory for several communities to join together for a water supply. There was a certain amount of local jealousy between different towns, and it was an extraordinarily difficult task to get them to come together for a water supply which would eventuate in the communities getting their water more cheaply. Hitherto there had been no authority with compulsory powers which would enable it to dictate to the municipalities what they were to do, and he for one would like to see the Ministry of Health with wider powers than it now had. At present the Ministry called meetings and tried to get people into line, but it had no means of compelling them to come into line even if so doing was for their own good. He felt sure that for the benefit of the community, if we had a really good Ministry and that Ministry well served, there would be great advantages in giving it wider control than it now had. He had been at one time in favour of setting up independent water commissioners who should act in a very similar capacity to the electricity commissioners in this country, but he felt sure there would be great objection to setting up another independent body, and that we should have to look to the Ministry of Health. He did not know whether the Ministry had in mind introducing any measure which would give larger powers in this respect. It was vital to get particulars with regard to rainfall and run off, wells and underground sources, but such information could only be got if people voluntarily sent it in. The compensation water was fixed on a figure which was an assumed average rainfall for the drainage area. The promoters gave their figure, and there was seldom any difficulty in arriving at the average rainfall within a few per cent., and then it was argued before the Committee as to what proportion of the run off was to be left in the stream. It was generally assumed for the purpose of water supply that a reservoir was constructed capable of balancing the run off from the drainage area during the three driest consecutive years, and having arrived at that figure the Committee

determined what proportion of that should be allowed to run down the stream. A good many of these figures which had been given for water supply in the past had turned out to be incorrect, and certain municipalities were now afraid that if they disclosed information with regard to the run off they might be penalised in some way, and the compensation water increased. He would like compulsory powers to compel authorities to collect statistics and send them into the Ministry of Health, where they would be available for all people who wanted to see them, and would aid the Ministry in coming to a conclusion as to allocation of water supply. The system of compensation water based on average rainfall was ridiculous. The average rainfall did not determine the dry weather flow of any stream, and in nine cases out of ten if the dry weather flow of a stream was maintained, that was all that was required. In certain cases mills used far more than the dry weather flow, but this could be met much more readily by money compensation, and so far as concerned ordinary riparian owners or sanitary purposes, if you maintained the dry weather flow, these people would not be injured at all. The dry weather flow depended partly on rainfall and partly on geological conditions, and was the flow after a period of dry weather. He had known cases where the compensation water was fixed at an enormous number of times the natural dry weather flow of the stream, while in other cases it was fixed at much less than it should have been.

Mr. Joseph Hill (Bradford) said that on the question of allocation he believed that the Rivers Board would be the correct authority to control a particular watershed.

The Rivers Board should have power to allocate the water, fix the standard of purification, and should have the duties and powers of the Drainage Board. He would like to see an extension of the powers of the existing Rivers Boards to enable them to deal with all these questions. The first claim to any potable water should be the right of the Water Supplying Authority, but there are numerous cases where water existed unfit for drinking or domestic supply, but quite fit for industrial purposes, and where such conditions obtained the parties concerned should be able to help themselves. Supposing a firm were prepared to spend money to provide water for its own needs, and in doing so reduce the quantity of potable water used for trades purposes in the district, there ought to be some body or authority to settle these matters without going to Parliament.

Another thing calling for alteration is the matter of compensation water; compensation in money should not be thought of, for who could say what is the value of water in a river? Once there was a possibility of compensation being made in money all sorts of difficulties would arise. Although claimants may not be able to make good their claim, a lot of money would be spent fighting them. The best average condition of a river is generally best for everybody. The Water Supplying Authority should be required to leave the stream in the best average

state; having done this they should be allowed to take all the rest. As to underground water, a good deal more fuss was made about the question of underground water than was necessary. He thought the line on which we should go when dealing with allocation was what he had suggested, the setting up of a judicial body to whom experts could appeal.

Alderman JOHNSON (Bradford) said he agreed there should be an authority, but he was not willing to admit that the various waterworks throughout the country had failed in their duty. They had the duty of supplying water to very large centres, not merely for domestic purposes, but to keep alive manufacturing industries. He agreed that the smaller authorities in the country should not be deprived of the natural flow of water in order that it might be diverted to rich areas, like Birmingham, Leeds, Bradford and Sheffield, but he was not willing to agree that the Rivers Board should be set up as the authority. He was speaking with twenty years of service on the West Riding Rivers Board, and considered that Board was the last authority that he would like to have the settlement of the supply of water within the West Riding of Yorkshire. He would rather leave each little urban district council uncontrolled, for such a council, at all events, knew its own needs, whereas the other people merely desired to interfere. He would be willing to subscribe to what was mentioned years ago, that the Ministry of Health and Water Board should have some control. He had been willing at any time in his public life to subscribe to a Government Controlling Board, because he had felt during his many years of experience that the larger authorities passed through small areas, and deprived these of the natural flow which they used to have. If Parliament imposed on the larger authority the duty of supplying water to the smaller one, the supply was given with very great reluctance, and in a manner which caused the smaller authority great difficulty and cost. The water was not filtered, and if the smaller authority complained as to its quality they were told they must pay for it. The question was a very interesting one. He had followed it for the last twenty years, and we did not seem to be getting any nearer to a solution; but if he had to say one last word, a Rivers Board in this country, so far as he knew after twenty years' experience, was the very last authority the matter should be committed to.

Mr. J. HILL (Bradford) said he had spoken of an improved Rivers Board. He agreed with Alderman Johnson that most of the large cities had provided a cheap water supply, but he was rather thinking now of the smaller authorities who had the right to appeal to a larger authority, but instead of that carried on trying to get a supply for themselves. The results were not always satisfactory to everybody concerned.

Mr. WALO VON GREYERZ (Stockholm) said that in Sweden, if a city wanted a water supply, a right was granted for the city to the water in priority to anyone else. In the case of underground water, there

was no law with regard to compensation. A new water law had been passed only a few years ago, but this law had purposely said nothing about the ownership of underground water, because of the difficulties of laying down a general rule on the subject, and had left to the common court to decide each case as it arose. To assist the court in its decision and valuation, the court had the right to ask whatever outside expert advice seemed necessary. It was often considered enough if the city paid only for the land necessary for the water site, and not for the water, if the landowners did not use that water for their own purposes. The land generally was paid at its commercial value plus 50 per cent. If, however, the landowners already used the water, in some cases the city had had to give them compensation in the form of water from the city supply. But in the case of diverting river or lake water for supply purposes, the above-mentioned new water law had to be applied. According to this law, Sweden was divided into five parts, in each of which was a water board. The chief of this water board was a judge, and at his side he had an hydraulic engineer. No one had the right to build in a river or a lake, or to divert water therefrom, unless permission had been given by the water board. If the water was diverted for other purposes than power, compensation was paid in money ; if the water was diverted for power purposes, compensation might be in the form of electricity, if the owner of the water rights wished to have compensation in that form. Generally the land, necessary for the water site, as in the case of underground water, was paid at its commercial value plus 50 per cent., and so was the water when already used for power or other purposes ; but when the water was not yet used, it was paid only at its value. In no case, as far as the speaker knew, water diverted from a river or lake for water supply purposes had been compensated by pumping or drawing water from another source.

As to the question whether a community can be forced by law to participate in an enterprise of another community for the purpose of common water supply or sewage disposal, there is not yet any such law in Sweden. But according to the new Water Law mentioned above, a community or an individual who wishes to use a sewer of another community or individual, cannot be denied such use, but has to bear any additional cost arising from such use as well as part of the original cost of construction and maintenance.

Dr. Jan Smit (Amsterdam) said that he did not know of any legal difficulties about water rights in Holland. The question was as simple as could be imagined. Most supplies were municipal. Payment was not made for ground water, but the municipality had to buy the land in which the water was, and as far as he knew no difficulties arose. Only a few private companies supplied water, and these got their supply from bare land where there were no rights. Water was not often taken from the river—Rotterdam was the only case that he remembered, and in that

case there was so much water that nobody cared. Holland was a land where there was plenty of water and a licence was needed to add more to a river, no licence is needed for taking it out.

Mr. C. H. Roberts (Westminster) said he was interested in the remarks made on the question of compensation water. He thought this matter would have to be tackled before long if municipalities were to get the ample water supplies which they were in need of. Various methods had been suggested for affording compensation when water was taken from running streams for the supply of towns, but there were so many different cases that the matter was quite a complicated one. For instance, the previous speaker had referred to a water supply in Holland where the water was taken from a large running river. The question of compensation rarely arose in cases of that sort, but the acute cases were those where the supply was taken from small streams which supplied rural requirements on their way down to the sea or to meet a larger stream. If the whole of those small streams were taken the rural interests were very much prejudiced, and the question arose how could they best be compensated. In the past there was no doubt at all that a great number of towns had given more water in compensation than was fair to themselves, and some revision of the practice was very necessary, and should be made. Many towns in this country—he did not know what happened elsewhere—were short of water partly because they were giving compensation in water to streams in an amount larger than was necessary for the interests they were compensating.

He was one who considered that compensation should generally be given, having regard for the national interest, in the form of water or works rather than in money. At the same time he realised that each case must be considered on its merits, and that others were cases where money compensation might be allowable, if compensation was in fact needed.

PRESENT STATUS OF WATER WORKS PRACTICE IN SWEDEN.

By Alfred Jerdén.

Chief of the Municipal Water Works at Malmö.

Sweden is a large country though relatively sparsely populated. Its superficial area is 448,460 square kilometres (173,150 square miles) or about 5 per cent. of the total area of Europe. On January 1, 1923, the population amounted to 5,987,520 and the density of population to 14 inhabitants per square kilometres (35 inhabitants per square mile) or about the same as in U.S.A., but only $\frac{1}{14}$th of the density of population in England. Of the people 1,813,177 live in the 111 cities and about 250,000 in small country towns and similar communities with more than 1,000 inhabitants. Of the cities three have more than 100,000 inhabitants, and 36 above 10,000. Thus one-third of the population of Sweden live in communities, in which, as a rule, it is advisable, on account of a relatively great density of population, to lay down one water supply for the whole community. This solution of the water problem has been applied extensively. Not less than 85 per cent. of the Swedish cities have municipal waterworks. As only a few of the smaller cities are without waterworks, the cities provided with such waterworks embrace together not less than 98 per cent. of the total population of the cities. Within the various cities an average of 95 per cent. of the inhabitants are supplied with water from the municipal waterworks. Thus most of the people in the cities enjoy the advantages provided by waterworks. In the following pages the natural resources, as far as water is concerned, will be set forth, and an account given of the Swedish waterworks.

THE PRESENCE OF WATER.

The rock foundation of Sweden consists largely of primary rocks. On account of its homogeneous structure, it cannot collect ground water to any noteworthy extent. The looser layers of earth consist almost entirely of the post-glacial formations, which arose in connection with the great glacial periods of northern Europe. As these formations to a large extent consist of clays and very fine sand, they do not contribute to forming any considerable ground-water streams.

Only when this material has been sorted by the melting water of the glaciers, have water bearing sand and gravel appeared. It is especially worthy of note that the rivers running under the glaciers have worn the stones round and washed away the fine particles, leaving the remarkable rubble-stone ridges, which at the present time rise above the surrounding country and constitute interesting memorials of the glacial periods. On account of rocks and other irregularities projecting into the ridges there are often great difficulties in using the ground water.

Precipitation is relatively small and only averages 515 mm. a year. It is fairly evenly distributed over the whole year, with somewhat less precipitation in the spring than in the autumn as a rule. It is estimated that at least one-third of it is carried off by the rivers, which fact is due to the low mean temperature and the resultant low evaporation. On their way to the sea the rivers pass through a great number of lakes, the total surface area of which amounts to not less than 8 per cent. of the whole area of the country. In Sweden is to be found, in point of size, the third great lake of Europe, Vänern, with a surface area of 5,568 square kilometres (2,150 square miles).

From this general survey it may be gathered that ground water occurs relatively sparingly, while there are no difficulties in furnishing the cities of the country with water from the numerous lakes and rivers.

The first waterworks distributing water with sufficient pressure to carry it to the upper storeys of dwellings, were built early in the sixties. The most complete collection of statistical data on the Swedish waterworks is to be found in the " Statistical Data " of the Swedish Association of Municipal Engineers (Svenska Kommunal-Tekniska Föreningen, or S.K.T.F.), and the data given below have been compiled from statistics from this source for 1922.

WATER CONSUMPTION.

The water consumption *per capita* is relatively small in Swedish cities, due partly to the fact that manufactories using great quantities of water often have waterworks of their own. If we deduct the water used for manufacturing purposes (which in the 20 larger cities averages 25 per cent. of the total consumption in these cities) the consumption of those cities, where the water is generally metered, reaches a daily average of 80 litres (17.6 imperial gallons) *per capita* reckoning the average over a full year, and 120 litres (26.4 imperial gallons) in cities not metered. Thus cities not metered to any considerable extent consume 50 per cent. more than cities with meters. In the case of ground-water plants the consumption is somewhat lower than in the case of surface-water plants. Water used for manufacturing purposes is generally controlled by meters, but only in 10 per cent. of the cities is the entire consumption controlled by meters. In the other cities the domestic consumption is largely not controlled. The meters used are generally rotary meters ; to some extent volume meters occur, most often in the form of disc meters.

GROUND-WATER PLANTS.

Water-works engineers in Sweden have endeavoured in the first place to obtain ground-water for the water requirements of the cities. As mentioned above, the natural resources are not so well adapted to serve this purpose, but in spite of this fact they have succeeded to a remarkable degree, due partly to the small size of the cities. Not less than about half the number of Swedish cities use exclusively ground-water. The two largest cities, Stockholm and Gothenburg, fill only a minor part of their requirements with ground-water, but the third city of Sweden, Malmö, with a population of 115,000, uses exclusively ground-water. Here it has been possible because of a preglacial waterbearing sand-stratum in the vicinity, which on account of a dislocation in the rock surface has withstood the action of the glaciers. The condition of the ground-water in its natural state is usually good, and 38 cities use the water without any special treatment. When purification is necessary, it is generally for removing iron, present, however, in easily oxidized compounds. The largest iron-content amounts to six milligrams per litre (p.p.m.). The purification is commonly effected by aeration and in gravel and sand filters of the open type. Only in two places are pressure filters to be found. Where there are natural sand strata, but the quantity of ground-water is small, plants for producing artificial ground-water have been rather extensively built. In this case the surface-water is first purified by filtration and then conducted by open basins or pipe-wells into the sand strata.

SURFACE-WATER PLANTS.

Of the cities using surface-water half the number take their water from lakes and the others from rivers. On account of the relatively suitable condition of the looser layers of soil, the numerous lakes and the low density of population, the water in lakes as well as rivers is generally a good raw material for the water-works. The amount of suspended matter is small and the water usually but slightly coloured. Only a few cities have such a situation that they have to use surface-water coloured by vegetable matter. The number of bacteria in the raw water averages at the twelve largest surface-water plants 875 per cubic centimetre. Thus surface-water is well adapted for purification in ordinary slow sand filters, and the rate of filtration averages 100 mm. (about four inches) per hour. Through this treatment the bacteria are reduced from the above mentioned 875 per cubic centimetre in the raw water to 36 in the purified water. Plants using water coloured by vegetable matter avail themselves of the same method of purification, although this is not sufficient for decolourising the water. A couple of smaller plants use rapid sand filtration in combination with the addition of aluminium sulphate. During the present year two cities, using water from rather densely populated drainage areas, have built rapid filters with disinfection by chlorine gas. Some smaller municipalities

and private works use rapid filters in conjunction with disinfection by either chlorine or ozone. In this connection it may be mentioned that chlorine was discovered by the Swede Scheele as early as 1774.

PUMPS.

There are only five Swedish cities with their sources of supply situated so high as to render pumping superfluous. In the others the necessary pressure has to be obtained by means of pumps. Among the latter works 30 per cent. are equipped with centrifugal pumps exclusively, and only 10 per cent. have piston pumps exclusively. The driving power is generally furnished by electric motors, taking their current, as a rule, from some hydro-electric power station; only 5 per cent. of the works do not employ such driving power. Of the latter the greater number use water-power directly driving the pumps. The reserve machinery of the works is driven by oil motors, gas motors, steam engines or by electric motors with power from a different source from the other motors.

PIPE SYSTEM.

The water-works distribute the water through mains and service pipes. The former consist almost without exception of cast-iron pipes, the latter of cast-iron as well as wrought-iron pipes. Only to a small extent are there mains of wrought-iron pipes, then usually covered with jute-cloth drenched in asphalt. The mains are planned for conducting water not only for normal consumption but also for fire-extinguishing purposes. Fire hydrants are placed at about every 100 metres (110 yards), and almost without exception entirely below the ground surface. For the manufacture of pipes as well as mountings there are regulations worked out by the S.K.T.F. On the premises the water is distributed by service pipes, generally of wrought-iron with mountings of metal. The installations are covered by regulations and special instructions mainly worked out in close agreement with the standards of the S.K.T.F.

RESERVOIRS.

As pressure regulators reservoirs are used almost exclusively. Half the total number of waterworks have their reservoirs situated on such a natural height that towers become unnecessary. The reservoirs are generally made of reinforced concrete. The reservoirs are intended to serve for equalising the variations in the daily water consumption, as well as for holding a reserve supply for fire-extinguishing purposes, the capacity of which must be at least 300 cubic metres (about 10,600 cubic feet), when the reservoir is situated on a natural height, and 100 cubic metres (about 3,530 cubic feet), when the reservoir is placed in a tower.

FIRE PROTECTION.

It has been emphasised above that the mains as well as the reservoirs are planned with a view of preparedness for fire extinction. Other parts of the works are also adapted to serve this purpose, and thus the water-

works fill the minimum requirements laid down by the fire-insurance companies, viz., to be able to supply at any time at least 1,600 litres (352 imperial gallons) per minute through at most six adjacent fire hydrants with a pressure in the main not below 30 metres (100 feet). The observance of these regulations increases the erection cost of the plants, especially ni smaller cities, but in return a safe protection against fire is obtained. Even within buildings there are fire hydrants in certain cases, and to a less extent sprinkler installations.

ECONOMIC PARTICULARS.

The waterworks in all Swedish cities, with one sole exception, are owned by the cities themselves. The water rates are generally calculated so as to make the revenue cover the expenses for the running of the works as well as for interest and amortisation of the erection cost. Where there are no meters, rates are calculated on the assessed value of the estate, the number of rooms, etc. In 10 per cent. of the cities the water consumption for domestic use is still free. On an average for the twenty largest cities, the income from the water sold is 12 öre per cubic metre (about 8d. per 1,000 imperial gallons) of distributed water.

* * * * * * *

Even though natural resources have not been the most abundant in many instances, it has been possible for the cities of Sweden to obtain good water-supply at a relatively low cost. However, the cities are growing, and the increase in water-consumption is more rapid than the increase in population. Even if the consumption to a certain extent can be restricted by a more general use of meters, the consumption will probably tend ever to increase. As the demand grows, the water sources will become less satisfactory. The ground-water will probably be insufficient and the surface-water polluted as places get more densely settled, and also pollution will occur from industrial wastes. It will be necessary to plan in time in order to be able to meet the greater demands, and to reserve certain lakes for water-supply purposes, in order to make the proper methods of purification as simple as possible, so that good water may be obtained at a reasonable cost even in the future.

DISCUSSION.

Mr. BINNIE (the Chairman) said that Mr. Jerdén was to be congratulated on having condensed into so few pages so much information. One or two points would be rather interesting for discussion, for instance the question of the use of meters in connection with domestic supply.

Mr. HARRISON P. EDDY said that in the United States the metering of their supplies, particularly in the eastern part of the country, was very largely done, and it was found almost without exception that the nett result had been a reduction in the consumption. It was true, however, that as time went on there was a tendency for that consumption to increase. Notwithstanding the completeness with which the supplies of many American cities were metered, they were still using great quantities of water. Mr. Jerdén had pointed out the large use of water for industrial purposes. He had spoken of 25 per cent. of the entire supply, and this use of water for industrial purposes was an important factor in the large consumption of water in many of the cities of the United States. Many of those cities were essentially industrial cities, and certain of them used great quantities of water. That was one of the reasons why their supplies were so large, but it was only one of several. It was perhaps important to add in that connection that not only was a large quantity of process water derived from the municipal supply, but in addition to that in many cities some of the industries furnished their own supply, so that when a hundred gallons *per capita* was spoken of, for the municipal supply, the actual total supply of water in some cities was increased considerably above that by the industrial supply taken from the ground or sources other than the municipal supply.

Mr. BINNIE (the Chairman) said that the rate per head in this country was about twenty gallons, and did not differ from the figure given for Sweden in Mr. Jerdén's paper. He (the Chairman) had always been astounded by the amount of water used per head in America or Canada, where the usual consumption was about eighty or one hundred gallons per head. Leakage accounted for some of this, but when in Ottawa he had gone into this question, and had found that although twenty gallons per head was due to leakage in the pipes, certainly eighty gallons per head was used. Could Mr. Eddy offer any explanation? Was it due to a much larger use of baths in working class homes?

Mr. EDDY said this was one cause. Of course, there were differences in different parts of the country, but it might be taken that throughout the north-eastern States and largely in the south a large proportion of the houses had baths. Even certain industrial developments for people who had come largely from Southern Europe and Asia were provided with baths. Better class houses often had several baths, and when travelling on the Continent and in Great Britain he could not

but notice the great difference in that respect. In the modern American hotels, even small ones, practically every room had its bath, whereas here he had the greatest difficulty in securing a room with a bath except in a very few hotels. No more baths may be taken in the States, but probably more water per bath is used. This did not account for the entire difference. In American houses there were probably more fixtures—faucets, sinks, laundry tubs, etc.—and as they put in more fixtures they had more leaks. Another thing was that in certain parts of the United States there was a considerable irrigating of lawns and gardens. There was probably more of that, and he believed there was more of street watering than there was here, because of the difference in climate, although, of course, in the United States the climate varied in different parts of the country.

Mr. Fuller (New York) said that in comparing the consumption of water in Great Britain with that in the United States, it must be remembered first of all that the American gallon was smaller than ours. It took six of their gallons to equal five of ours. One reason for the larger consumption was that the American people were wasteful. He knew of communities where the leakage was from fifty to sixty gallons *per capita*. Another element was that although the rainfall in the Eastern States was larger than here, its distribution was very irregular, and a great deal of water was used for lawn sprinkling and irrigating. Then much more water was used for manufacturing. Water that was wasted went in ways that were hard to explain, and he had had one interesting experience that came from gauging sewers at a time when there was neither lawn sprinkling in summer nor the great waste due to frost in winter. In the city of Toledo the sewers had been gauged partly in spring and partly in the fall. In that city there was practically one hundred United States gallons of water *per capita* per day pumped at the station. It was found that if you added together the sum of the water which was registered by the individual meters you could rarely account for more than 75 per cent. of the water pumped. This figure of seventy-five gallons was checked by the sewers. For the purpose of this investigation the city was divided into three parts, East Toledo, where there were large foundries was one part, and there the average consumption was about fifteen to sixteen gallons per head per day. The better class residential districts showed a figure of forty-five to fifty, and the intermediate class streets and boarding house district showed thirty-five. This was also the average amount for the whole city; thirty-five gallons out of seventy-five was all that was used for domestic consumption. On top of that there were the uses of very large office buildings, very substantial commercial uses, industrial uses and wastage. It was in the larger houses where the servants were not watched very carefully that wastage came in to a large extent. The genuine use of water in America for domestic purposes was not more than forty (equal to thirty-five imperial gallons) per head per day.

The other elements were very largely associated with climatic conditions and the fact that Americans were a wasteful people.

Mr. C. H. Roberts (Westminster) said it was interesting to hear from Mr. Fuller that in America where the conditions were somewhat different from those here, the legitimate consumption of water, i.e., the consumption after subtracting avoidable waste, etc., was about thirty-five gallons per head per day; in this country the corresponding figure was only about one-half that amount. Without any restriction of the legitimate use of water, and with houses generally well provided with w.c.s and baths, many of our large cities actually use for domestic purposes very little more than twenty gallons per head per day. The metering of supplies, which had the tendency to restrict not only the waste and improper use of water but also the legitimate use of water necessary to healthful conditions, was unpopular in this country and looked upon by health authorities with disfavour. On the other hand, the causes of waste and unnecessary consumption were receiving more and more attention every year. He had been engineer for a waterworks in Scotland some years ago, and when he first went north he had been puzzled to know why the consumption of water in Scottish towns was higher, nearly twice as much, than it was in English towns. High domestic consumption was generally explained in the first place by what might be called undue or improper consumption, and secondly by waste, pure and unadulterated. Undue consumption came largely from habits formed by the consumers of water. He had taken the trouble to go round several districts with a waste inspector on washing and other days to see how water was used. He found that people who had been used to a plentiful supply of water, never for a moment thought of conserving their supply. A tap was turned on over a washing tub. If, when the water was required no longer it was a little trouble to turn it off, it was left running. Such habits as these, to take only one illustration, were responsible to a large extent for unnecessary or undue consumption. Whatever was to be done to control consumption, whether by metering or otherwise, it was necessary to keep in mind that a plentiful supply of good water was essential to health, and that nothing should be done to discourage the provision of such a supply.

With regard to the reduction of waste and improper consumption, a careful study of the causes of high consumption was necessary. The problem was often a very complicated one. If he were to strike any particular note, it would be this. The prevention of waste and undue consumption was a matter which could not profitably be left to a waste inspector, as it often was; it should receive the serious attention of an engineer with considerable experience in solving consumption problems if satisfactory results of waste prevention efforts were to be obtained.

Mr. Jerdén replied briefly to the discussion.

SUPPLY OF DRINKING WATER IN THE DUTCH EAST INDIES.

By Dr. Jan Smit,

Private Lecturer on Microbiology, University of Amsterdam.

The supply of drinking water in the tropics is one of the most important problems of modern colonisation, and in the Dutch East Indies it has been regarded as such by the Government during the last forty-five years.

I intend to give you a very short survey of what has been reached in that lapse of time.

The problem is particularly difficult, because the houses in the cities are built wide apart, as is the custom in tropical countries (the total area of Batavia is nearly that of Paris). This brings about heavy costs of installation, so that central supplies can only be laid in a few of the larger towns, and in those smaller ones, where conditions are particularly favourable. Working expenses are paid almost entirely by the European population, which is relatively small, viz., 170,000 in the whole colony of whom nearly 75,000 are found in the ten larger cities. Considering this, it will be understood that in most of the rural towns central supply is impossible. In these every house still has its own well, as in former days every city-house had. Often this water is of inferior quality, because the wells are wrongly made and mostly lay open to all sorts of contaminations, which are so frequent in tropical regions. Matters are worse still in the houses of the non-European population. Most of these, as well as the natives, are entirely devoid of hygienic understanding, and drink whatever they can get. They are not afraid of bathing and defecating in the highly-polluted rivers, and at the same time drinking from the same source. These habits have made typhoid fever and dysentery endemic diseases, and made central water supply urgent wherever European and native population live near to one another, as is the case in the cities.

The same lack of hygienic understanding makes the sanitation of plantations and estates difficult. In many parts of the colony it has become the custom, therefore, to provide coolies with weak tea several times a day, whilst water drinking is strictly forbidden. The same is done in the army when in the field. As the natives prefer tea, when

they can get it easily enough, it is comparatively easy to avoid the drinking of river-water, and therefore these measures have been a great success in the sanitation of the estates on the east coast of Sumatra, especially in fighting bowel diseases. Death-rate for amœbic dysentery fell from 22.5 per 1,000 in 1903 to 2.5 in 1905, and has remained at this point, or in some years fell lower still.

The first important improvement in city water supply came in 1877, when the artesian supply to Batavia commenced. There were seventeen artesian wells, yielding 6,000 cub. m. a day, and for the first time the water was brought into the houses. Gradually other cities followed, until now the Dutch Government has spent more than twenty million guilders in the construction of new supplies. By now nearly forty supplies have come into use.

FOUR SYSTEMS HAVE BEEN ADOPTED.

1. For the supply of important seaport towns, where excellent water is a question of hygienic and economic necessity, natural springs are used, situated in mountainous regions, often at considerable distance. The recently finished new supply of water to Batavia is obtained from Mount Salak, some forty miles away. There, on the stony slopes, covered with forests, a number of magnificent springs of a very large total capacity are available. The water needs only to be collected in a semi-circular channel, filled with stones and covered with a concrete plate, and it flows down the long way to Batavia, lying about 1,000 feet below. A few miles before the city is reached, the water is collected in a huge reservoir (20,000 cub. m., nearly one day's supply), from where it is pumped to the city. Other large cities, as Sourabaya, Semarang, Pasoeroean, Medan, have adopted the same system. The case of Pasoeroean is remarkable, because the spring used there has such a large capacity (2.4 cub. m. per second), that the larger part of the water is used to drive turbines and pumps, which send the rest of the water to the city.

2. The city of Bandoeng, situated in the mountains of Western Java, makes use of a rich artesian supply, lying some 50 m. deep. The high-grade water spouts up under considerable pressure. More than 600 small artesian supplies are scattered all over the colony. Some of them are rapidly diminishing in capacity, or have become saltish.

3. A third method is underground drainage, as used in Cheribon. There a large area of land is reserved for the collection of ground-water in deep drains. The installation is old and not quite satisfactory, and will be improved before long.

4. Filtration of river-water is a method quite new in the colony. River-water is heavily polluted, and carries much brown or red clay, so that slow sand-filtration requires considerable technical supervision (even more so in the tropics than in Europe). Rapid filtration not being quite safe, the method was not gone into, before chlorination came to assist. Shortly the city of Sourabaya has started this means

of supply. Spring water being short, rapid filtration of river water with alum was installed, and the filtrate is treated with gaseous chlorine (system Ornstein).

The city of Makassar (Celebes) has been the first to complete its river-water supply, where slow sand filtration is used. Here, too, chlorine was introduced.

Many a question still requires further consideration and extensive study, and therefore an experiment station was erected in 1922 in the neighbourhood of Batavia, where all matters affecting drinking water and sewage will be studied in the light of tropical conditions. One of the most important considerations will be the supply of drinking water in the native villages. The use of chlorine is impossible there, and a method is wanted to purify the filthy river water, in a cheap and simple manner, which the unskilled native can perform with the least possible trouble and without the possibility of spoiling the effect or poisoning his fellow-citizens!

The question is difficult, but some progress was quickly made by using lime, by the action of which the water readily gives a sparkling clear filtrate of a very remarkable purity. Besides, the technicalities are very simple, and it may be hoped that the solution of this urgent problem will be found in this direction.

The following is a survey of the most important supplies :—

Name.	Date when finished.	Source of water.	Daily quantity in cub. m.	Total capital outlay. Florins.	Price of the water. Pence per cub. m.
Batavia—					
Old supply ..	1877	artesian	6,000	602,000	5
New supply ..	1923	spring	30,000	9,000,000	5
Sourabaya—					
Spring supply ..	1903	,,	11,750	2,132,000	6
River-water ..	1922	river-water	—	1,103,000	6
Semarang	1913	spring	12,000	1,100,000	2—12
Bandoeng	1911	artesian	16,000	1,420,000	2—13
Pasoeroean.. ..	1918	spring	3,600	640,000	2—7
Medan	1908	,,	2,550	806,000	1—4
Malang	1915	,,	1,960	342,000	5
Cheribon	1890	ground-water	600	137,000	4
Tandjong Karang ..	1921	spring	500	245,000	2—9
Menado	1923	,,	1,200	600,000	3—7
Makassar	1923	river-water	3,000	2,400,000	3—9

OZONIFICATION OF THE WATER OF THE RIVER NEVA.

By Professor S. Rashkovich.

During the years 1906 to 1914, a large amount of work was done in the laboratory and at the experimental stations of the Technical Sanitary Institute of Petrograd in connection with the treatment of drinking water by means of ozone from the health point of view.

Among the various chemical substances that have been proposed for use in the sterilisation of water there are two that have been adopted in a greater number of cases than any others, viz. : Chlorine and ozone, and the use of these two substances is always followed by the following results.

1. Complete sterilisation of drinking water by means of excess of chlorine involves the presence in the sterilised water of *free chlorine*, giving a disagreeable and piquant taste which necessitates de-chlorination by means of hypo-sulphites.

2. When ozone is used for the sterilisation of drinking water any excess remaining in the water disappears rapidly and completely, because it is not stable.

OZONE IS SOLUBLE IN WATER.

Mayfert has given the following figures for the solution of ozone in water according to the temperature of the water.

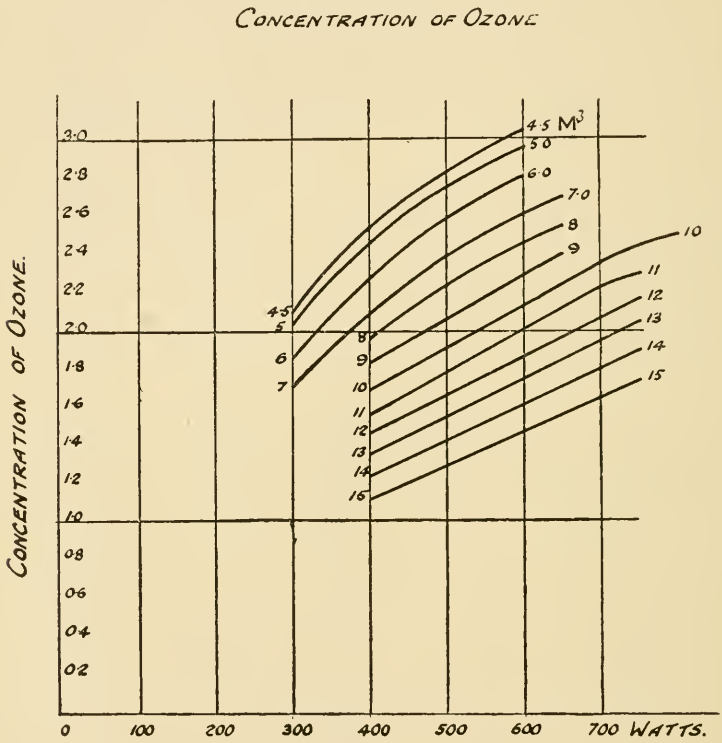
Temperature. C.	Millig. of ozone dissolved in 1 litre of water.	Co-efficient of solubility.
0.0	39.4	0.641
11.8	29.3	0.500
19.0	21.0	0.381
27.0	13.9	0.270
32.0	7.7	0.195
47.0	2.6	0.077
55.0	0.6	0.031
60.0	0.0	0.000

Ozone is produced either by electrical discharge or by chemical methods, but up to the present the latter method has been too costly. In practice, ozone is produced from atmospheric air, or from pure oxygen in a closed apparatus known as an "ozonateur" in which the atmospheric air or the oxygen is activated by the discharge between two electrodes of high tension alternating current. There are many kinds of ozonateurs, but they can all be divided into two principal groups, viz.:

1. Dielectric ozonateurs with non-conducting electrodes.
2. Non-dielectric ozonateurs.

The best known systems are those of Tyndale-Friese, Siemens-Halske, Otto Marmier-Abrahams.

DIAGRAM NO. I.



No. 1.—Efficiency of Siemens-Halske ozonateur, according to the number of watts and volume of air.

The question of the amount of ozone obtained is of great importance both theoretically and practically, and I have myself carried out a series of experiments in order to determine the amount of ozone produced according to the quantity of air used and the amount of electric current in an ozonateur of the Siemens-Halske type in which the electrodes had a surface of 2 square metres with a current of 6,000 volts.

The following results were obtained :—

USING 500 WATTS.

Cub. met. of air per hour.	Concentration of ozone in grmmes. per cub. met.	Grms. of ozone obtained.	Watts expended per gramme of ozone.
5	2.75	13.75	36.3
6	2.58	15.50	32.2
7	2.40	16.80	29.7
8	2.24	17.90	28.0
9	2.08	18.70	26.7
10	1.92	19.20	26.0
11	1.80	19.70	25.4
12	1.66	19.20	25.1
13	1.54	20.02	24.9
14	1.42	19.88	25.15
15	1.30	19.50	25.6

It will be noticed from the above table that as the volume of air passing through the ozonateur was increased the concentration of the ozone decreased, but at the same time the quantity of ozone obtained also increased. On the other hand a very interesting phenomenon appears, viz. that the total quantity of ozone obtained is at its maximum when the volume of air passing through the ozonateur has reached 11 to 12 m^3 and begins to diminish when the volume of air has reached 15 m^3, while the expenditure of energy per gramme of ozone also increases.

The results of my long experiments in connection with the production of ozone by the Siemens-Halske apparatus are given in the two diagrams on pp. 360 and 363.

In diagram No. 1 is given the amount of ozone in grammes per m^3 of air together with the number of watts for ozonateurs of 300 to 750 watts and with the use per hour of 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and 15 m^3 of air.

In diagram No. 2 is given the quantity of ozone in grammes per kilowatt-hour with the number of watts varying from 300 to 750 and with the use per hour of 4.5, 5, 6, 7, 8, 9, 10, 11 and 15 m^3 of air.

With regard to this diagram it should be noted that the maximum efficiency from one Siemens-Halske ozonateur with a total active electrode

surface of 0.2 m^2 is when the volume of air used is 12 m^3 per hour and the number of watts is 400, as will be seen from the following table.

EXPENDITURE OF ELECTRIC ENERGY PER GRAMME OF OZONE IN WATTS.

Volume of air.	Electric current used. 400 watts.	500 watts.	750 watts.
1	23.5	26.0	30.6
11	23.0	25.4	29.5
12	22.8	25.1	28.0
13	22.9	24.9	28.2
14	23.4	25.1	28.2
15	24.1	25.6	28.3

The efficiency of the ozone also depends upon the effect of the luminous emanation from the high tension electric discharge and this permits me to suggest that the ozonification of air is a radiographic phenomenon and that the emanation of the discharge produces ultra-violet rays which condense the oxygen into ozone, but the ozone obtained which passes through this emanation and is accompanied by an increase in the temperature, destroys itself (reaction inverse).

The humidity of the air had a great effect upon the efficiency of the ozone. The quantity of watery vapour in the atmospheric air according to the temperature and density of the saturated vapour is as follows :—

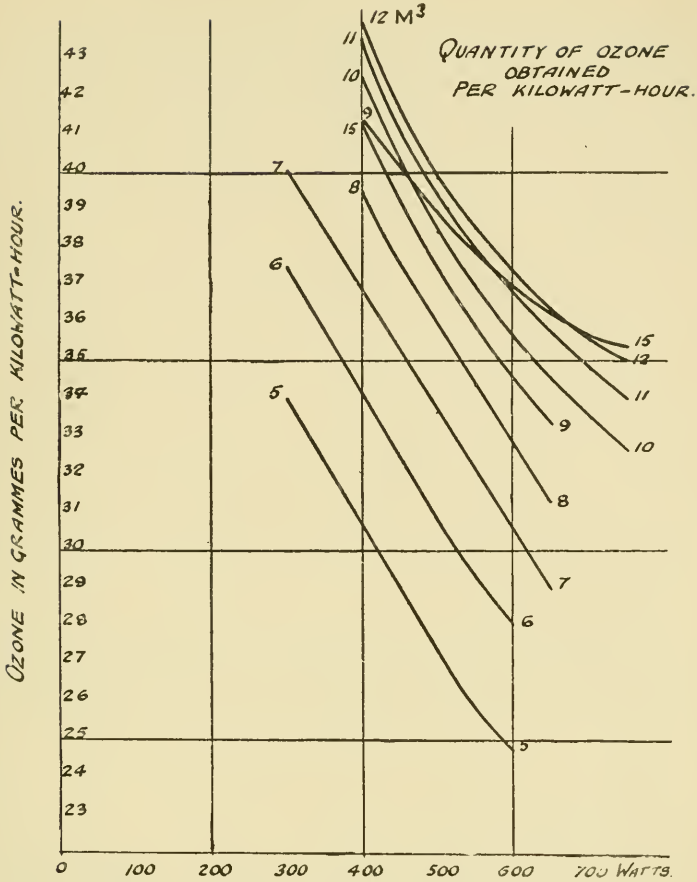
Temperature. Degrees C.	Grammes of water.
– 20	1.10
– 10	2.35
0	4.88
10	9.37
20	17.18
25	22.87

The best method of drying the air for use in ozonification is to reduce the temperature by refrigeration to the lowest possible degree.

In connection with the sterilisation of drinking water by means of ozone a large number of appliances and methods for mixing the ozone with the water have been devised. These methods may be divided into the following groups :—

1. Atomising the water in an atmosphere of ozone.
2. Blowing the ozone into the water.
3. Spraying the water in an atmosphere of ozone.
4. Producing an emulsion of water and ozone (drawing in the ozone with a current of water. (Otto Emulsifier).
5. Contact of the water with the ozone on the surface of certain materials. (The Hay-Lussac " Tour Classique.")

DIAGRAM NO. 2.



No. 2.—Efficiency of Siemens-Halske ozonateur, according to the number of watts and volume of air.

The most important factors in the mixing of water with ozone are the *duration of contact,* thorough mixing, the volume of the air used and the concentration of the ozone.

The volume of air ozonified and the concentration needed depends upon the quantity of ozone required to saturate the water as it is only after saturation (viz., the sterilised water must give a blue reaction with iodide and starch) that one can state that the water is sterilised and for this purpose it is very important to study the quantity of ozone in the air that has passed through the sterilisateur column after being mixed with the water.

In my experiments I have found that the duration of the period of contact of the water with the ozone should not be less than 10 to 15 minutes.

The absence of organic matters in suspension is the essential condition for sterilisation of water and good filtration is absolutely necessary. If the filtered water contains little oxidisable organic matter sterilisation will be satisfactory and the cost of the ozone reduced to the minimum.

Coagulation with sulphate of alumina or other chemical substance is the best method of clarifying and removing the colour in water.

Coagulation in itself removes colour in water and reduces the amount of soluble organic matter in the water to a great extent, up to 60—75 per cent. When the water is subjected to preliminary coagulation prior to sterilisation the cost of the ozone is reduced to the minimum and the water is well saturated with the ozone, i.e., the work of the ozone is concentrated upon the sterilisation. There is no need to fear an excess of ozone in the water as this would be rapidly absorbed by the organic matter remaining in the water.

In 1909 the Petrograd Municipality entrusted the Technical Sanitary Institute with the work of carrying out experiments in the treatment of the Neva water with ozone, and an experimental station was constructed capable of dealing with 10 cubic metres of water per hour.

The objects of these experiments were :—

1. To determine the effect of the ozone.
2. To determine the cost of the treatment with ozone of the Neva water after slow filtration.
3. To determine the cost of the treatment of the Neva water with ozone after preliminary coagulation followed by rapid filtration. The series of experiments lasted continuously for 10 hours and each hour the water was examined in its crude state, after filtration and after treatment with the ozone for

1. Colour.
2. Alkalinity.
3. Oxidation by the Kübel method.
4. Number of micro-organisms in 1 c.c.

At the same time special attention was given to the question of technical control and the following measurements were made each hour :—

1. The quantity of water.
2. The amount of electric energy to produce the ozone.
3. The volume of air used.
4. The amount of power required for pumping the air.

Finally the concentration of ozone was determined each hour :—

1. In the air pumped into the steriliser column.
2. In the air leaving the column after sterilisation.
3. In the water after sterilisation.

The problem was to determine from the technical and economic point of view which method of preliminary purification gave the best results, slow filtration or rapid filtration after preliminary coagulation.

The sterilisation of very large quantities of water may be considered in two ways :—

I.—THE STERILISATION OF WATER AFTER SLOW FILTRATION.

10 days experiments.

2 *Siemens-Halske ozonateurs.*

	Filtered water*.	Water after treatment with ozone. Mean reduction.
1. Oxydation in mg. $KMnO_4$ per litre	23—32 mlgrm.	13.6% (4.1%—22.1%)
2. Colour in c.c. of the normal solution†	18—42 c.c.	80% (67.6%—89.2%)
3. Number of organisms in 1 c.c...	25—1,120	3 micro-organisms (1—8)

* The filtration was not sufficient.
† 2.5 grm. ferrum chloride.
0.5 grm. cobaltum sulphuric.
5 c.c. acid hydrochloric 1.19.
100 c.c. water.

II.—THE STERILISATION OF WATER AFTER COAGULATION AND RAPID FILTRATION.

6 days experiments.

1 *Siemens-Halske ozonateur.*

	Raw water.	Water after coagulation and filtration.	Average reduction.
1. Oxidation in mlgrm. $KMnO_4$ per litre	25—28	8—14	56.68%
2. Colour in c.c. of the normal solution	35—45	2—16	79.13%
3. Number of micro-organisms ..	55—800	2—54	93.2%

Treatment of the coagulated water with ozone caused the following reductions :—

Oxidation .. average 15.91% (11.1—22.2)
Colour .. ,, 37.52% (31.8—50.0)
Number of organisms average 1.55 in 1 c.c.

Average results of experiments in the treatment of Neva water with ozone :—

	Filtered water.	Water filtered after coagulation.
1. Number of ozonateurs	2	1
2. Return of ozone to the ozonateur after sterilisation	Yes.	No.
3. Volume of air in m^3	13.83	13.4
4. Concentration of ozone in grammes per m^3	2.97	2.07
5. Do. do. after sterilisation ..	0.58 (20%)	0.89 (44%)
6. Quantity of free ozone in the sterilised water in grammes per m^3	0.27	0.49
7. Quantity of water treated in m^3	7.40	8.08
8. Amount of ozone per m^3 of water in grammes	4.35	1.93
9. Electric energy used per m^3 of water in watts	118	65.8
10. Volume of air used per m^3 of water, in m^3	1.86	1.68
11. Effect of the treatment with ozone :—		
(*a*) Reduction of oxidation ..	13.6%	15.9%
(*b*) Removal of colour	80%	37.52%
(*c*) Number of micro-organisms ..	3	1.55
12. Period of contact	12 minutes	11 minutes.
13. Electric energy used for 1 gramme total ozone in watts	22.0	19.95
14. Electric energy expended per gramme of ozone used for sterilisation in watts	23.0	36.48*

* This figure is explained by the fact that the system was working without the return of ozone to the ozonateur.

From the last table it will be seen that sterilisation of water from the river Neva required twice as much electric energy (118 watts) when the water was subjected to slow filtration as when it was subjected to coagulation followed by rapid filtration (65.8 watts), and in the latter case 44 per cent. of the ozone was not used.

Sterilisation of the water that was coagulated was effected with less concentrated ozone (2.07) than without coagulation (2.95) ; the quantity of free ozone in the water that was coagulated was nearly twice as much (0.49) as in the water not coagulated (0.27) which provides a much greater guarantee of complete sterilisation (water coagulated 1.55 micro-organisms without coagulation 3 micro-organisms).

Cost of treatment of 1 cub. met. of water from the River Marne

	Centime.
1. Cost of electric energy for the ozone (1 kilowatt at 5.5 centime)	0.25
2. Cost of electric energy for refrigeration of the air..	0.01
3. Cost of staff	0.50
4. Cost of pumping the water	0.20
Total—Centime 0.96 = 0.175 cents U.S.A.	

In April, 1908, experiments were carried out in Paris with the Siemens Halske Friese system, with the following results :—

Cost of treatment of 1 cub. met. of water from the River Marne.

	Centime.
1. Cost of electric energy for the ozone..	0.085
2. Cost of electric energy for pumping the air.. ..	0.095
3. Cost of staff	0.500
4. Cost of pumping the water	0.040
Total—Centime 0.720 = 0.132 cents. U.S.A.	

My experiments with water from the River Neva gave the following results :—

Cost in kopecks of treatment of 1 m^3 of water from the River Neva.

	Filtered water.	Water coagulated and filtered.
1. Electric energy for the ozone at 3.5 kopeck per kilowatt	0.370	0.200
2. Electric energy for pumping the air..	0.100	0.100
3. Cost of staff	0.200	0.200
4. Cost of pumping the water	0.015	0.015
5. Cost of refrigeration	0.025	0.025
Gold kopeck	0.710	0.540
= cents U.S.A.	0.355	0.27

Adding the cost of the coagulant, viz., 0.25 kopeck, the comparative costs are :—

Kopeck..	0.710	0.79
= cents U.S....	0.355	0.395

CONCLUSIONS.

1. The amount of ozone required for the treatment of water from the River Neva after slow filtration is from 4 to 5 grammes per m^3 of water, with a concentration at the least of 2 grammes of ozone per m^3 of air, and a period of contact of fifteen minutes.

2. The amount of ozone required for the treatment of water from the River Neva after coagulation and rapid filtration is from 1.5 to 2 grammes per m^3 of water, with a minimum concentration of 1.5 grammes of ozone per m^3 of air, and a period of contact of ten minutes.

3. As the water of the River Neva contains large quantities of humic matter (soluble organic matter) its treatment with ozone necessitates preliminary coagulation prior to filtration in order to obtain satisfactory results.

PURIFYING THE WATER SUPPLY OF LENINGRAD.

By C. Kovroff.

Chief Engineer, Leningrad Waterworks.

Leningrad is supplied with water from the River Neva, the intake being near the middle of the town where the water is highly polluted and dangerous to health.

Taking the water from the River Neva in the very centre of the town was a great mistake from the very commencement in the year 1858, and later on, in the year 1874, three special pumping stations were erected for raising the water to supply separate parts of the town. These were situated at some distance from the principal water-raising station in still more unfavourable places, as they drew the water from the river at points considerably lower down than the chief station.

During the last few years serious attention has been given to remedying this mistake with the object of preventing the frequent epidemics of typhoid and cholera, which raged to such an extent that they threatened to be a national calamity.

It is to be regretted, that until recently, only palliative measures were taken for improving the quality of the water. Slow sand filters were constructed at the principal pumping station, and the separate pumping stations were closed and the water taken from the chief station, but in consequence of economy and wrong calculations, the water filtering at the principal station did not attain its object, and the filtered water was not satisfactory. Owing to the great speed of filtration and the absence of storage reservoirs of sufficient capacity for the filtered water, also the unavoidable unequal work of the filters, being overburdened during the day and out of work during the night, the filters could not supply the requisite quantity during the hours of maximum demand, and it became necessary to pump raw water into the storage reservoirs, with the result that the water provided for consumption even after the construction of the sand filters was very little better than the raw water.

The average mortality in Leningrad from typhoid fever for twenty-four years (1887-1910) was 69.5 per 100,000 inhabitants with maximum of 114 and minimum of 27. The years where there were fewer deaths than the average number, were the following: 1890–1894; 1902–1904; 1909–1910. In mentioning these years with regard to water-supply conditions, it appears that they coincided with the years when from

various causes the amount of raw water added to the filtered water was reduced, or when the population at the time of cholera took less water from the water pipes and used it in a boiled state.

In 1911, one part of the town previously using unpurified water in its natural state was provided with coagulation in sedimentation tanks, rapid filters and further purification by ozone. Later on, from the end of 1913, all the water added in its raw state at the chief pumping station was purified by chlorine and from 1914 all the water was chlorinated at the chief station and delivered into the city. Since the above-mentioned years the mortality from typhoid fever has considerably decreased and from 1911 to 1923, that is for thirteen years, the average mortality from typhoid fever was 34 per 100,000 with a maximum of 51 and a minimum in 1923 of 10, the rate falling rapidly from 1918 down to an average of twenty-five cases.

It is still more evident how the unsatisfactory conditions of the unpurified water were the cause of the spread of Asiatic cholera as shewn in the following table :—

Year.	Cases.	Deaths.	Remarks.
1892	4253	1364	Unpurified water
1893	2888	1313	Do. do.
1894	4410	2220	Do. do.
1895	493	279	Do. do.
1908	16635	7273	Do. do.
1909			
1910	4200	1869	Do. do.
1915	653	183	Water purified
1918	12047	4305	Water unpurified
1919	918	488	Water purified
1920		5	Do. do.
1921		23	Do. do.
1922		2	Do. do.
1923		0	Do. do.

From the above table one can see how great a number of victims of the population of Leningrad fell a prey to cholera and how the absence of purified water served as an immediate cause of the epidemic by infecting new arrivals. We have every reason to believe, that the cholera epidemic lasting three years successively, 1908-9-10, was due to the water.

The cholera in 1918 was due to the absence of chloride of lime in Leningrad as there was no possibility of procuring it owing to the fact that the chemical works where the chloride of lime was prepared, were situated in districts occupied by battles during the civil war. As soon as there was the possibility of procuring the chloride of lime and renewing the chlorination, the epidemic immediately ceased and was not renewed, being limited to a few cases of fresh arrivals, coming from places where the epidemic was still raging.

It is therefore perfectly clear, that the Neva water is dangerous to health in the highest degree, but if there is no other source of procuring water, it is impossible to avoid using it, and we must therefore adopt every possible means of cleansing and purifying it before the population makes use of it.

We have already pointed out the measures that were taken for the last few years with the object of purifying Neva water. Such measures were taken in two directions, firstly researches were made for drawing water into Leningrad from an uninfected source (the Ladoga Lake) and secondly a new method was used for purifying the water, temporarily till the completion of the work for substituting the new source. With this object in view in 1910 a filter station was built with rapid American filters and coagulation of the water followed by purification by means of ozone. This station was finished in 1913, and was capable of dealing with 60,000 cubic metres of water in twenty-four hours.

At the same time experiments were carried out by a Special Commission in purifying the Neva water with ozone after filtration in slow sand filters at the rate of nine inches per hour and more, and also in purifying the raw water and mixed water, namely, filtered water with raw water added to it.

The conclusion arrived at by the Special Commission of Experts was that with respect to sanitary conditions the results of ozonising the Neva water at the filtro-ozone station of the Leningrad waterworks were unsatisfactory. Of course, these results do not give us any reason why we should reckon the ozonisation to be an unfit means of purifying water, as it was found that by giving a contact of longer duration absolutely certain results were obtained unconditionally, giving perfectly pure water. But this arrangement of a longer contact demands considerable apparatus, increasing the cost of construction and greater expense for fuel, therefore from the economical point of view it requires a great outlay of money.

With regard to the results obtained at the small experimental stations chlorination was used, after a series of experiments at the experimental station, for purifying all the water drawn from the main pumping station as much as 300,000 cubic metres in twenty-four hours. For this purpose the slow sand filters were converted into sedimentation tanks and rapid filters of rectangular type erected. This alteration is not yet finished, so that the water raised to the sedimentation tanks is chlorinated by chloride of lime, after that it is left to settle for four hours and is then passed through a rapid filter, which acts solely as a preliminary filter as the water is not coagulated. This alteration was made as a temporary measure and was to be changed when water was available, drawn from the Ladoga Lake. Notwithstanding the absence of preliminary treatment of the water and with the process of chlorination only without ozonising the results obtained were sufficiently satisfactory and not inferior to ozoned water. With an average dose of 1 milligram. of active chlorine per litre in 1923 the following results were obtained : the number of bacterial colonies in 1 cubic centimetre decreased on an average from 564 to 20,

that is 97 per cent., the number of *B*.coli communis found in samples of 100 cubic centimetres was 19.3 per cent. and in 400 cubic centimetres—35.7 per cent., that is, the result with regard to the percentage of *B*.coli communis is analogous to the result of purifying the water with ozone. For purifying the water with chlorine it was taken in its raw state, whereas for ozonising the water, it was carefully filtered. In this respect the ozonised water is definitely inferior to the chlorinated as it is proved by the experience of many years that it can be used even with unfiltered water. The continuous chlorination of all the water pumped into the network of pipes at the main pumping station has been done for ten years. The quality of water improved from the moment chlorination was commenced. As unfiltered water is subjected to purification, the average dosing of active chlorine is 1 milligram per litre. The water after being chlorinated is not dechlorinated ; and smell is noticeable only in those seasons when the water contains much vegetable matter. With a lower temperature in the water the quantity of chlorine is lessened. In the winter, after the ice has blocked up the river, the water becomes cleaner and it is possible to reduce the dose to from 0.5 to 0.7 milligrams of active chlorine per litre, whereas in summer the dose is increased to 2.5 milligrams depending upon threatening gastric epidemics. The increased dose during the summer months is connected with the pollution of the River Neva by navigation. During 1918 and the following years up to 1922, a considerable improvement was noticed in the quality of raw water, partly from the decrease of inhabitants in the town, the number of which was reduced from 2.5 million to 700 thousand and partly in consequence of a complete stoppage of navigation, therefore, during the winter months, when the Neva is covered with ice, there is every possibility of reducing the dose of active chlorine to 0.5 milligrams per litre.

For chlorinating the water, chloride of lime is chiefly used, containing 33 to 35 per cent. active chlorine, though at times for want of lime containing the normal quantity of chlorine it has been necessary to make use of an inferior quality containing 15–20 per cent. which had laid long in the open air. During the period of the German war when it was impossible to obtain chlorine for preparing chloride of lime, an electrolytical method of dissolving common salt (NaCl) was temporarily used for obtaining hypochlorite of natrium. For this purpose a special generating station was erected with two Diesel motors and a belt-driven continuous current dynamo together with electrolisers with platinum anodes and carbon cathodes on the Shuckert system.

This station was started in December, 1916, and operated until May, 1918, when the platinum and carbon poles were worn out and as there was no possibility of renewing them, the hypochlorite arrangement had to be stopped and it was found necessary to return again to purifying the water by chloride of lime. The hypochlorite of natrium is a solution (NaOCl) containing from 12–13 kilograms of active chlorine in 1 cubic metre of the solution ; for producing one kilogram of active chlorine from 7 to 8 kilograms of kitchen salt was required. Later on, in 1918, experi-

ments were made with liquid chlorine, but these experiments gave no positive results, as there was no possibility of obtaining the proper apparatus for the purpose.

Passing on to the economical aspect and the trustworthiness of both methods of purifying water it is necessary to give the preference to chlorination.

The filtro-ozone department, built in 1911–1913 at the station on the other side of the river worked more or less satisfactorily, that is, though it did not give absolutely sterilised water, the percentage of purification was not less than 99.5 per cent.–99.99 percent., while the cost of purifying with ozone did not exceed 0.5 copeck per 100 vedros, taking from 40 to 50 watt-hours per cubic metre.

From the beginning of the war, however, and later on, when the cost of fuel rose in comparison to former years by two and a half times, the purifying of water with ozone was utterly impossible from an economical point of view. Besides this, the bacteriological question had to be considered owing to the absence of several materials necessary for repairs. A lower ozone concentration occurred and a mass of ozonators were out of use, in consequence of which the percentage of purification some times dropped to 70 per cent. instead of 99 per cent.

After due consideration of all points it was decided to adopt chlorination of the water after coagulation, settlement and filtration. After experiments had been made, it appeared sufficient to fix the dose at 0.2 milligrams of active chlorine per litre and to inject the chloride of lime solution after the water had passed through the towers of sterilisation into the general collective pipe Under these conditions the duration of contact is four hours, while the particles of water, after being mixed with the solution of chloride of lime, pass through the connecting pipes to the storage reservoir. The change to chlorination was made on the 30th of June, 1923, so that besides the reduction of expenses for purifying the water to one-fifteenth of the previous cost, the bacteriological results obtained are considerably higher and the percentage of purification has once more risen to the former 99 per cent.

Judging from existing data, as to the best means for purifying water whether by ozonisation or chlorination on a large or a small scale, it is impossible to come to any other conclusion than that all the advantages are with chlorination as the cheapest and simplest method, not requiring any complicating mechanisms or many persons to look after the apparatus.

In view of this I suggest :—

1. That from a technical point of view, the only certain method of purifying water is chlorination.

2. That having at disposal such a powerful and inexpensive method of purifying water that is dangerously polluted, the adoption of this method prevents the spread of water borne epidemics.

3. That sufficiently satisfactory results are obtained even when purifying untreated muddy water.

4. That for attaining perfectly satisfactory results it is necessary to subject to chlorination only well-filtered water, and in this case an insignificant dose of active chlorine is sufficient, viz.: from 0.2 to 0.3 milligrams per litre of water, so that even a special duration of contact is not required.

5. Taste of chlorine remains only when raw water is chlorinated, the chlorination of water freed from organic substances does not give a disagreeable taste and the chlorination with small doses does not require dechlorination.

6. That in order to secure the greatest efficiency, it is indispensable that filtered water only should be chlorinated.

In conclusion it is necessary to point out, that the Leningrad town waterworks in all circumstances, both during the period of the universal war and during the period of the civil war, worked regularly. In particular it is necessary to note how the Soviet Government, notwithstanding, all the difficulties of its economical and political existence during the period of the economical blockade and civil war in striving for the sanitary well-being of Leningrad manifested an immense solicitude for maintaining the town waterworks in good order and thus removed the causes of epidemic diseases and the possibility of their development. By this means it placed Leningrad in the best of sanitary conditions with regard to spreading and stoppage of typhoid and cholera in comparison even with the time before the war. The results of the attention were clearly proved in the above mentioned data showing the decrease of mortality from typhoid fever and the prevention of cholera epidemics.

DISCUSSION.

Mr. L. CANTOR (Sanitary Engineer to the Government of Palestine) said that the development of Palestine would depend very largely on its water supply. Jerusalem, Hebron, Nablus and Bethlehem got their water from springs and cisterns in which rain-water was collected. There was no filtration or treatment of any kind carried out anywhere except at Jerusalem, where water was brought from the Wadi Arub and the ancient pools of Solomon. This water was treated. At Tiberias the water was taken from the lake, the town being on the lake itself. There had been outbreaks of cholera there and several deaths, and it was found the women would go to the lake for their daily supply of water and bathe their feet at the same spot as they took water from. The Government took action, and water was only available at two or three points. To these places the women had to go for their supply, and the sanitary inspector put a dose of bleaching powder into each jar of water as it went by.

The public water supplies are safeguarded by regular bacteriological examinations carried out at the Government laboratories. Private supplies are examined upon application. Purification and treatment is applied when necessary. The physical, chemical and bacteriological standards of purity for potable water have been adopted as used for safeguarding the army during the Palestine campaign, viz.: (*a*) The attainment of one meter transparency; (*b*) the absence of chemical evidence of recent sewage contamination, and (*c*) the absence of colon bacilli from 1 c.c. of the water. Compared with British municipal standards, they are admittedly low, but have proved satisfactory in practice. Higher requirements would at present be impossible as it would compel the closure of the majority of the wells and cisterns. Schemes for improving the water supplies for Jerusalem, Haifa, Jaffa, Nablus, Hebron and Tiberias are being prepared. As previously stated, schemes for Jerusalem and Tiberias are well in hand. Government loans are made to the villages for improving their water supply upon approved schemes.

As to the consumption of water, it had been interesting to hear the opinions of Mr. Eddy and Mr. Fuller on the eighty and one hundred gallons consumed per head in America as compared with thirty-five or forty in England. In Jerusalem, last year, they had got on at one time with as little as two gallons a head a day. There was an extreme shortage of water. The rainfall for the year went as low as nineteen inches, the usual being about thirty-six inches, and the cisterns ran short about July. The cisterns being empty, the inhabitants fell back on the town supply. They were compelled to go to standpipes and draw their daily ration; and this was limited to two petrol tins per family whatever the number of that family might be. In every Jewish home now being built, complete sanitation was provided, but fifteen gallons a head per day seemed to suffice for all their needs. There might be more demand when the water became more palatable, but

at present fifteen to twenty gallons was the maximum throughout Palestine. The water authority advocated the use of shower baths so as to keep down the consumption of water, but he (Mr. Cantor) knew cases where people would take a complete bath with only one litre of water. In this connection he might remark that the chief reason people used less water in England than in America was because we used wash basins instead of running water in bath-rooms.

Mr. J. S. Alford (the President), in closing the proceedings of the Conference, said he thought all would agree that the Conference had been a success; and that expression might be used of every one of the sessional sittings they had had. He congratulated the gentlemen from the Continent of Europe on the facility with which they had been able to take part in a discussion carried on in English: the great trouble about the venue of the next Conference was what was to be done about the Englishmen who could not speak French. He thanked the chairmen of the various sessions, and the secretary, who had been an important factor in the Conference's success.

The proceedings then terminated.

INDEX

PAGE

Acarinæ 250
Achorutes viaticus 250
Acreage of Local districts.. .. 13
Activated Sludge, Colloid Chemistry as Applied to. By John Arthur Wilson. (*Illustrated*) 110
— — Dewatering. By Langdon Pearse 126
— — Discussed by Harrison P. Eddy, H. Kessener, Dr. H. T. Calvert, F. W. Harris, G. W. Fuller, F. C. Temple, J. H. Garner, G. P. Harvey, H. Taylor, Dr. Jan Smit, Mme. Wibaut, T. F. Hambleton, R. Eaton, Dr. Ardern, C. H. Hurd, and T. Chalkley Hatton.. 97
— — Discussed by Dr. Mc Gowan, W. H. Makepeace, Dr. Imhoff, Dr. Ardern, Harrison P. Eddy, W. D. Scouller, A. J. Martin, Joshua Bolton, Paul Hansen and J. A. Wilson 139
— — Fertilising Value of. By Victor H. Kadish.. .. 134
Activated Sludge Plant, Houston, Texas, Operation of. By J. C. McVea 81
— — — Withington Sewage Works. By Dr. Edward Ardern.. 75
Activated Sludge Process, Elasticity of. By Joshua Bolton 116
— — — in India and the East. By Prof. Gilbert J. Fowler.. 122
— — — Spiral Circulation in the. By C. H. Hurd .. 93
Address. By J. S. Alford .. 1
Administration, Sanitary, in England and Wales. By I. G. Gibbon. (*Illustrated*) .. 5
Ædes Ægypti. 45–46–47
Aerating activated sludge plant.. 81
Aeration chambers.. 75
Alford, J. S. Opening Address .. 1
— Vote of thanks to the Minister of Health 31

PAGE

American and English Drainage. By G. C. Whipple 261
— Model Plumbing Code. By W. C. Groeninger 293
— Practice in the Disposal of Refuse. By Samuel A. Greeley. (*Illustrated*) 316
Ames Crosta Activated Sludge Plant 116
Analytical results of activated Sludge Plant 79–83
Ankylostome Infection 38
Anopheles Ludlowi 49
— Maculatus 40–50
— Minimus 50
— Mosquito 32
Anti Malaria Work.. 41–47
— — — in Singapore .. 51
Ardern, Dr. Edward, on Activated Sludge Plant—Withington Sewage Works. 75
Artificial Filters 206

Bergstrom, John, on Electrically Driven Centrifugal Pumps for Water Supply and Sewage Disposal 53
Bezault, B., on Sanitary Work carried out in France during recent years 186
Biological Purification of Sewage.. 207
Bolton, Joshua, on Elasticity of the Activated Sludge Process 116
Boulnois, H. Percy, on Fifty Years of Sanitation in England .. 17
Bureau of Engineering, Pennsylvania 21
By-laws of Local Authorities .. 15

Canadian Sewage Disposal Plants 279
— — — — Discussed by G. W. Fuller 288
Centrifugal Pump Curve.. .. 56
— Pumps 54
— — for Water Supply and Sewage Disposal. By John Bergstrom 53
Chemical Analyses of Waste Waters 241

PAGE

Clifford, W., on Friction of Sewage Sludge in Pipes 59
Colloid Chemistry as Applied to Activated Sludge. By John Arthur Wilson. (*Illustrated*). 110
Combined Sewerage discussed by C. G. J. Ratcliff, F. C. Temple, A. J. Martin, Dr. Coleman, H. C. H. Shenton, W. von Greyerz and A. P. I. Cotterell 175
— System of Sewerage with Limited Rainwater. By Walo von Greyerz 170
Concrete Tubes 167
Contact Beds 207
Costs of Pumping 55
— — Working small Activated Sludge Plants.. .. 103
Cotterell, A. P. I., Introduction.. 146
County Borough Councils.. .. 14
Culex Quinquefasciatus 45

Dairy Trade Waste Waters, Purification of. By H. A. van Ysselsteyn. (*Illustrated*) .. 231
Dairy Waste Treatment 224
Dallyn, F. A., on Operating Experiences with Canadian Sewage Disposal Plants 279
Dewatering Activated Sludge. By Langdon Pearse 126
— Sludge 88
Dibdin, W. J., on Sewage Purification 215
Discussion on Activated Sludge. By Harrison P. Eddy, H. Kessener, Dr. H. T. Calvert, F. W. Harris, G. W. Fuller, F. C. Temple, J. H. Garner, G. P. Harvey, H. Taylor, Dr. Jan Smit, Mme. Wibaut, F. T. Hambleton, R. Eaton, Dr. Ardern, C. H. Hurd, and T. Chalkley Hatton 97
— — — — By Dr. Mc Gowan, W. H. Makepeace, Dr. Imhoff, Dr. Ardern, Harrison P. Eddy, W. D. Scouller, A. J. Martin, Joshua Bolton, Paul Hansen, and J. A. Wilson 139
— on Canadian Sewage Disposal. By G. W. Fuller .. 288
— — Combined Sewerage. By C. G. J. Ratcliff, F. C. Temple, A. J. Martin, Dr. Coleman, H. C. H. Shenton, W. von Greyerz, and A. P. I. Cotterell 175

PAGE

Discussion on Disposal of Snow. By Harrison P. Eddy, Dr. Coleman and W. von Greyerz 184
— — Grit Catchers. By A. J. Martin, W. H. Makepeace, W. Clifford, Dr. Ardern, T. Chalkley Hatton and F. C. Temple.. 196
— — House Drainage. By Dr. Coleman, W. Scott and H. A. Roechling 270
— — Houston Plant. By T. Chalkley Hatton 85
— — Malaria. By Sir Ronald Ross, Dr. Carnwath, Col. Clemesha, Sir Malcolm Watson, W. J. E. Binnie, J. K. Hoskins, L. Johnson, Dr. Scharff, A. J. Martin, Dr. Jan Smit, F. C. Temple and J. S. Alford 47
— — Milwaukee Plant. By T. Chalkley Hatton 90
— — Pipe Work. By Prof. E. R. Matthews, W. J. Oakley, T. Chalkley Hatton, W. H. Makepeace and A. P. I. Cotterell 153
— — Public Health Administration. By J. K. Hoskins, Dr. W. B. Mercer and T. Chalkeley Hatton 27
— — Pumps and Friction in Pipes. By J. S. Alford, Harrison P. Eddy, G. W. Fuller, C. F. Beckenn, G. A. Wigley, J. W. Cameron, A. J. Martin, H.W.Taylor, C. H. Heathcote, L. Johnson and F. C. Temple 65
— — Purification of Water. By L. Cantor and J. S. Alford 375
— — Refuse Disposal. By J. C. Dawes and J. A. Priestley 333
— — Sanitary Work in France. By F. C. Temple .. 189
— — Sanitation of Dwellings. By C. G. Klaarhamer, J. W. Lockwood, H. A. Roechling, F. C. Temple, L. Borring, L. Cantor, A. P. I. Cotterell and H. C. H. Shenton 302
— — Sewage Purification. By W. J. Dibdin 215
— — — Treatment. By Dr. Mercer, Nandy Hoskins, Dr. Ardern, Dr. Calvert, G. W. Fuller, Dr. MacLean Wilson, H. Kessener and G. P. Harvey 252

PAGE

Discussion on Sewerage in Low Countries. By Harrison P. Eddy, A. J. Martin, C. G. Klaarhhamer, C. Sharp, F. C. Temple and A. P. I. Cotterell 165
— — Water Sources. By R. G. Hetherington, G. W. Fuller, W. J. E. Binnie, J. Hill, Alderman Johnson, W. von Greyerz, Dr. Jan Smit and C. H. Roberts 341
— — Waterworks in Sweden. By W. J. E. Binnie, Harrison P. Eddy, G. W. Fuller and C. H. Roberts.. 353
Disposal of Industrial Wastes in the United States. By Harrison P. Eddy 217
— — Refuse, American Practice in the. By Samuel A. Greeley. (*Illustrated*). .. 316
— — — by Separation and Salvage. By James Gair .. 325
— — Snow. Discussed by Harrison P. Eddy, Dr. Coleman and W. von Greyerz .. 181
— — — Utilisation of Sewers for the. By Erland Hedstrom 181
Drainage of Low Lands 158
Drains Fifty Years Ago 17
Duties of Local Authorities .. 14

East Indies, Drinking Water in.. 356
Eddy, Harrison P., on Disposal of Industrial Wastes in the United States.. 217
Elasticity of the Activated Sludge Process. By Joshua Bolton 116
Electrically Driven Centrifugal Pumps for Water Supply and Sewage Disposal. By John Bergstrom 53
Engineering Bureau of the Pennsylvania Department of Health. By W. L. Stevenson 21
English and American House Drainage. By G. C. Whipple 261
— Practice in Sewer Pipe Work. By Edward Willis. (*Illustrated*) 147
Expenditure of Local Authorities 16
— on Sanitary Services .. 7

Fertilising Value of Activated Sludge. By Victor H. Kadish 134
Fifty Years of Sanitation in England. By H. Percy Boulnois 17

PAGE

Financial Loss from Malaria .. 35
Finland, Sewage Treatment in .. 243
Fowler, Prof. Gilbert J., on Activated Sludge Process in India and the East 122
France, Sanitary Work in.. .. 186
Friction in Pipes and Pumps. Discussed by J. S. Alford, Harrison P. Eddy, G. W. Fuller, C. F. Beckenn, G. A. Wigley, J. W. Cameron, A. J. Martin, H. W. Taylor, C. H. Heathcote, L. Johnson and F. C. Temple.. 65
— — Sewage Sludge in Pipes. By W. Clifford. 59
— — Sludge 62

Gair, James, on Refuse Disposal by Separation and Salvage .. 325
Gambusia Afinis Fish 35–46
Garner, J. H., on Historical Development of Sewage Purification Processes.. 204
Gibbon, I. G., on Sanitary Administration in England and Wales. (*Illustrated*) 5
Greeley, Samuel A., on American Practice in the Disposal of Refuse. (*Illustrated*).. .. 316
Griffith, Percy, on National Control and Allocation of Water Sources 335
Grit Catchers. Discussed by A. J. Martin, W. H. Makepeace, W. Clifford, Dr. Ardern, T. Chalkley Hatton and F. C. Temple 196
— — Screens and Storm Water Tanks in Sewage Disposal Works. By F. C. Temple. (*Illustrated*) .. 190
Groeninger, Wm. C., on American Model Plumbing Code .. 293

Harvey, Geo. Peel, on Sewage Treatment in Scandinavia and Finland 243
Hatton, T. Chalkley, on Sewage Disposal Plant for the City of Milwaukee, U.S.A. 86
Health Departments and Malaria Control.. 33
— — of Pennsylvania .. 21
Hedstrom, Erland, on Utilisation of Sewers for the Disposal of Snow 181
High-Pressure Pump Curve .. 56

PAGE

Historical Development of Sewage Purification Processes. By J. H. Garner 204
Hodgson, John S., on Two House Drainage Systems—with the Atlantic Between 298
Holland, Purification of Trade Waste Waters.. 224
Hopper-bottom Settling Tanks .. 85
House Drainage, English and American. By G. C. Whipple 261
— — Discussed by Dr. Coleman, W. Scott and H. A. Roechling 270
— — Two Systems—with the Atlantic Between. By John S. Hodgson 298
— Sanitation Fifty Years Ago 19
House Refuse Disposal Fifty Years Ago 19
Houston Plant. Discussion by T. Chalkley Hatton 85
Humus Tanks 210
Hurd, C. H., on Spiral Circulation in the Activated Process .. 93
Hydrolytic Tanks 212

Illustrations, 5–16, 110–115, 147–152, 190–195, 231–242, 312–320, 355–364
Imhoff Tanks 213
Incineration of Garbage 320
Incubation Period of Yellow Fever 44
Industrial Wastes Classified .. 217
— — Disposal of in the United States. By Harrison P. Eddy. 217
Introduction. By A. P. I. Cotterell 146

Jerden, Alfred, on Present Status of Waterworks Practice in Sweden 348
Johnson's Curve 191
Joints for Sewer Pipes .. 150–151

Kadish, Victor H., on Fertilising Value of Activated Sludge .. 134
Kessener, H., on Purification of Trade Waste Waters in Holland 224
Kinematic Viscosity of Sludge .. 61
Kovroff, C., on Purifying the Water Supply of Leningrad.. 369

Land Irrigation 205
Leningrad Water Supply.. .. 369
Le Prince, J. A., on Recent Progress in Malaria Control in the United States.. 32

PAGE

Lives Saved by Malaria Control.. 41
Local Authorities 9
Low Countries Sewerage. By B. A. Verhey.. 158

Malaria, a Rural Problem.. .. 34
— Control Campaigns.. .. 32
— — in the United States. By J. A. Le Prince 32
— Discussed by Sir Ronald Ross, Dr. Carnwath, Col. Clemesha, Sir Malcolm Watson, W. J. E. Binnie, J. K. Hoskins, L. Johnson, Dr. Scharff, A. J. Martin, Dr. Jan Smit, F. C. Temple and J. S. Alford 47
— Mosquitos 32
— Problems in Malay.. .. 39
Malay Peninsula, Sanitary Problems in the. By Sir Malcolm Watson 37
Marketable Fertiliser 87
McVea, J. C., on Operation of Activated Sludge Plants, Houston, Texas 81
Milwaukee Sewage Disposal Plant. By T. Chalkley Hatton .. 86
— — — — Discussed by T. Chalkley Hatton 90
— Water Supply 86
Modern Methods of Refuse Collection. By J. A. Priestley .. 310
Mosquito Breeding in Ricefields.. 49
— Lava.. 40
Municipal Life Fifty Years Ago.. 17

National Control and Allocation of Water Sources . By Percy Griffith.. 335
Non-County Borough Councils .. 14
Number of Local Districts .. 13

Office of Works Functions.. .. 153
Officers Dealing with Sanitation .. 8
Oospore lactis 253
Opening Address. By J. S. Alford 1
Operating Activated Sludge Plant–77–81
— Experiences with Canadian Sewage Disposal Plants. By F. A. Dallyn 279
Ozonification of the Water of the River Neva. By Prof. S. Rashkovich. (*Illustrated*) .. 359

Paris Green Larvicide 35
Pearse, Langdon, on Dewatering Activated Sludge 126

PAGE

Pennsylvania Department of Health, Engineering Bureau. By W. L. Stevenson 21
Percolating Filters 209
Pipe Lines for Sewage 59
Pipework. Discussed by E. R. Matthews, W. J. Oakley, T. Chalkley Hatton, W. H. Makepeace and A. P. I. Cotterell .. 153
Plumbing Code, American Model. By Wm. C. Groeninger .. 293
— Regulations 262
Podura aquatica 250
Pool-breeding Mosquitos 40
Population of Local Districts .. 13
Potato Flour Waste Treatment .. 228
Powers of Local Authorities .. 14
Pozzuolana 166
Present Status of Waterworks Practice in Sweden. By Alfred Jerden 348
Priestley, J. A., on Modern Methods of Refuse Collection 310
Progress in Malaria Control in the United States. By J. A. Le Prince 32
Public Health Administration. Discussion by J. H. Hoskins, Dr. W. B. Mercer and T. Chalkley Hatton 27
— — Nuisances in Pennsylvania 25
Pumping Conditions on the Rand 73
— Station at Stockholm .. 55
Pumps and Friction in Pipes. Discussed by J. S. Alford, Harrison P. Eddy, G. W. Fuller, C. F. Beckenn, G. A. Wigley, J. W. Cameron, A. J. Martin, H. W. Taylor, C. H. Heathcote, L. Johnson and F. C. Temple 65
Purification of Dairy Trade Waste Waters. By H. A. van Ysseteyn. (*Illustrated*) 231
— — Trade Waste Waters in Holland. By H. Kessener .. 224
— — Water. Discussed by L. Cantor and J. S. Alford .. 375
Purifying the Water Supply of Leningrad. By C. Kovroff .. 369

Rand Conditions of Pumping .. 73
Rashkovich, Prof. S., on Ozonification of the Water of the River Neva. (*Illustrated*) 359
Rateable Value of Local Districts 13
Refuse Collection, Modern Methods. By J. A. Priestley 310

PAGE

Refuse, Disposal by Separation and Salvage. By James Gair 325
— — Discussed by J. A. Dawes and J. A. Priestley .. 333
Regulations concerning Sanitation of Dwellings. By Prof. Klas Sonden 289
Rural District Councils 14

Sanitary Administration in England and Wales. By I. G. Gibbon. (*Illustrated*) . .. 5
— Problems in the Malay Peninsula. By Sir Malcolm Watson 37
— Water Board of Pennsylvania 22
— Work in France during Recent Years. By B. Bezault 186
— — — — — Discussed by F. C. Temple 189
Sanitation in England, Fifty Years of. By H. Percy Boulnois .. 17
— of Dwellings, Regulations concerning. By Prof. Klas Sonden 289
— — — — Discussed by C. G. Klaarhamer, J. W. Lockwood, H. A. Roechling, F. C. Temple, L. Borring, L. Cantor, A. P. I. Cotterell, and H. C. H. Shenton 302
Scandinavia, Sewage Treatment in 243
Septic Tanks. 211
— — Introduced 18
— Latrines 38
Settlement Tanks 76
Sewage Disposal Fifty Years Ago 18
— — and Water Supply, Electrically Driven Centrifugal Pumps for, By John Bergstrom 53
— — Plant for the City of Milwaukee, U.S.A. By T. Chalkley Hatton 86
— — Operating Experiences with Canadian. By F. A. Dallyn 279
— Works, Grit Catchers, Screens and Storm Water Tanks in. By F. C. Temple. (*Illustrated*) 190
Sewage Pumps 57
— Purification Processes, Historical Development of. By J. H. Garner 204
— — Discussed by W. J. Dibdin 215

PAGE
Sewage Sludge in Pipes, Friction of. By W. Clifford 59
Sewage Treatment in Scandinavia and Finland. By G. Peel Harvey 243
— — Discussed by Dr. Mercer, Nandy Hoskins, Dr. Ardern, Dr. Calvert, G. W. Fuller, Dr. MacLean Wilson, H. Kessener and G. P. Harvey 252
Sewer Pipe Joints 150–151
— — Work, English Practice. By Edward Willis. (*Illustrated*) 147
Sewerage Combined. Discussed by C. G. J. Ratcliff, F. C. Temple, A. J. Martin, Dr. Coleman, H. C. H. Shenton, W. von Greyerz and A. P. I. Cotterell 175
— in Low Countries. By B. A. Verhey.. 158
— — — — Discussed by Harrison P. Eddy, A. J. Martin, C. G. Klaarhamer, C. Sharp, F. C. Temple and A. P. I. Cotterell 165
— with Limited Rainwater, Combined System of. By Walo von Greyerz 170
Sewers Fifty Years Ago 17
— for The Disposal of Snow, Utilisation of. By Erland Hedstrom 181
— of Concrete.. 168
Smit, Dr. Jan, on Supply of Drinking Water in the Dutch East Indies 353
Sonden, Prof. Klas, on Regulations concerning Sanitation of Dwellings 289
Spiral Circulation in the Activated Process. By C. H. Hurd .. 93
Standard Viscometers 70
Stegomyia Mosquito 34–51
Steuernagel's Curve. (*Illustrated*). 191
Stevenson, W. L., on Engineering Bureau of the Pennsylvania Dept. of Health 21
Stockholm Pumping Station .. 55
Strawboard Waste Treatment .. 229
Stream Pollution Control.. .. 221
Streams Classified by Sanitary Water Board 26
Sugar Factory Waste Treatment.. 227
Supply of Drinking Water in the Dutch East Indies. By Dr. Jam Smit 356

PAGE
Sweden, Status of Waterworks in 348

Tarbett, R. E., on Yellow Fever Prevention Work along the United States Mexican Border 42
Temple, F. C., on Grit Catchers and Storm Water Tanks in Sewage Disposal Works. (*Illustrated*) 190
Trade Waste Waters in Holland, Purification of. By H. Kessener 224
Trass 166
Treatment of Industrial Wastes.. 220
Tropical Sanitarian Problems .. 37
Trough Latrines 39
Two House Drainage Systems—with the Atlantic between. By John S. Hodgson.. .. 298

Urban District Councils 14
Utilisation of Sewers for the Disposal of Snow. By Erland Hedstrom 181

Verhey, B. A., on Sewerage in Low Countries 158
Viscosity of Sludge 59–63
Viscometer for Sludge 62
Volume of Sewage *per capita* 67–131
von Greyerz, Walo, on Combined System of Sewerage with Limited Rainwater 170

War Camps and Malaria 33
Waste Water Purification Works.. 232
Water Carrier in Mexico 45
— Consumption *per capita* .. 349–353–354–355
— in the Dutch East Indies, Supply of Drinking. By Dr. Jan Smit 353
— of the River Neva, Ozonification of the. By Prof. S. Rashkovich. (*Illustrated*) .. 359
— Sources, National Control and Allocation of. By Percy Griffith.. 335
— — Discussed by F. G. Hetherington, G. W. Fuller, W. J. E. Binnie, J. Hill, Alderman Johnson. W. von Greyerz, Dr. Jan Smit and C. H. Roberts.. 341
—Supply in Pennsylvania .. 24
— — and Sewage Disposal, Electrically Driven Centrifugal Pumps. By John Bergstrom 53

PAGE

Water Supply in Malay 37
— — of Leningrad, Purifying the. By C. Kovroff 369
Water-Meters 54
Waterworks in Sweden. Discussed by W. J. E. Binnie, Harrison P. Eddy, G. W. Fuller and Roberts 35
— Practice in Sweden, Present Status of. By Alfred Jerden 348
Watson, Sir Malcolm, on Sanitary Problems in the Malay Peninsula 37
Wheatley, Rt. Hon. John, Words of Welcome 30
Whipple, G. C., on English and American House Drainage .. 261
Willis, Edward, on Sewer Pipe Work, English Practice. (*Illustrated*) 147
Wilson, John Arthur, on Colloid Chemistry as Applied to Activated Sludge. (*Illustrated*) .. 110
Withington Sewage Works—Activated Sludge Plant. By Dr. Edward Ardern 75
Words of Welcome. By Rt. Hon. John Wheatley. 30

Yellow Fever Prevention Work along the United States Mexican Border. By R. E. Tarbett 42
Ysselsteyn, H. A. van, on Purification of Dairy Trade Waste Waters. (*Illustrated*) . .. 231

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